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REPORT FOR CONSULTATION ON THE HARTFORD-SPRINGFIELD INTERSTATE AIR QUALITY CONTROL REGION (CONNECTICUT-MASSACHUSETTS)

National Air Pollution Control Administration
Washington, D. C.

April 1969

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service
National Air Pollution Control Administration

REPORT FOR CONSULTATION ON THE

HARTFORD-SPRINGFIELD

INTERSTATE AIR QUALITY CONTROL REGION

(CONNECTICUT-MASSACHUSETTS)

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
U. S. PUBLIC HEALTH SERVICE
CONSUMER PROTECTION AND ENVIRONMENTAL HEALTH SERVICE
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION
APRIL 1969

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PREFACE

The Secretary, Department of Health, Education, and Welfare, is directed by the Air Quality Act of 1967 to designate "air quality control regions" as an initial step toward the establishment of regional air quality standards. In addition to listing the major factors to be considered in the designation of region boundaries, the Act stipulates that the designation of a region shall be preceded by a consultation with appropriate State and local authorities.

The National Air Pollution Control Administration, DHEW, has conducted a study of the Hartford, Connecticut and Springfield, Massachusetts interstate urban area, the results of which are presented in this report. The boundaries of the Region*, as proposed in this report, reflect consideration of all available and pertinent data; however, the boundaries remain subject to revision suggested by consultation with State and local authorities. Formal designation will be withheld pending the outcome of that consultation.

The Administration is appreciative of assistance received either directly during the course of this study or during previous activities in the Hartford and Springfield interstate area from the Connecticut State Department of Health, the Massachusetts Department of Public Health, and the Lower Pioneer Valley Air Pollution Control District. Useful data was also supplied by the Capitol Region Planning Agency,

*For the purpose of this report, the word region, when capitalized, will refer to the Hartford-Springfield Interstate Air Quality Control Region (Connecticut-Massachusetts). When not capitalized, unless otherwise noted, it will refer to air quality control regions in general.

the Massachusetts Department of Commerce and Development, the Lower Pioneer Valley Regional Planning Commission, the TRC Service Corporation, the Connecticut Development Commision, the Connecticut Interregional Planning Program, and the Connecticut Clean Air Task Force.

INTRODUCTION

> "For the purpose of establishing ambient air quality standards pursuant to section 108, and for administrative and other purposes, the Secretary, after consultation with appropriate State and local authorities shall, to the extent feasible, within 18 months after the date of enactment of the Air Quality Act of 1967 designate air quality control regions based on jurisdictional boundaries, urban-industrial concentrations, and other factors including atmospheric areas necessary to provide adequate implementation of air quality standards. The Secretary may from time to time thereafter, as he determines necessary to protect the public health and welfare and after consultation with appropriate State and local authorities, revise the designation of such regions and designate additional air quality control regions. The Secretary shall immediately notify the Governor or Governors of the affected State or States of such designation."
>
> Section 107(a)(2), Air Quality Act of 1967

THE AIR QUALITY ACT

Air pollution in most of the Nation's urban areas is a regional problem. This regional problem demands a regional solution, consisting of coordinated planning, data gathering, standard setting and enforcement. Yet, with few exceptions, such coordinated efforts are notably absent among the Nation's urban complexes.

Beginning with the Section quoted above, in which the Secretary is required to designate air quality control regions, the Air Quality Act presents an approach to air pollution control involving coordinated efforts by Federal, State, and local governments, as shown in Figure 1. After the Secretary has (1) designated regions, (2) published air quality criteria, and (3) published corresponding documents on control

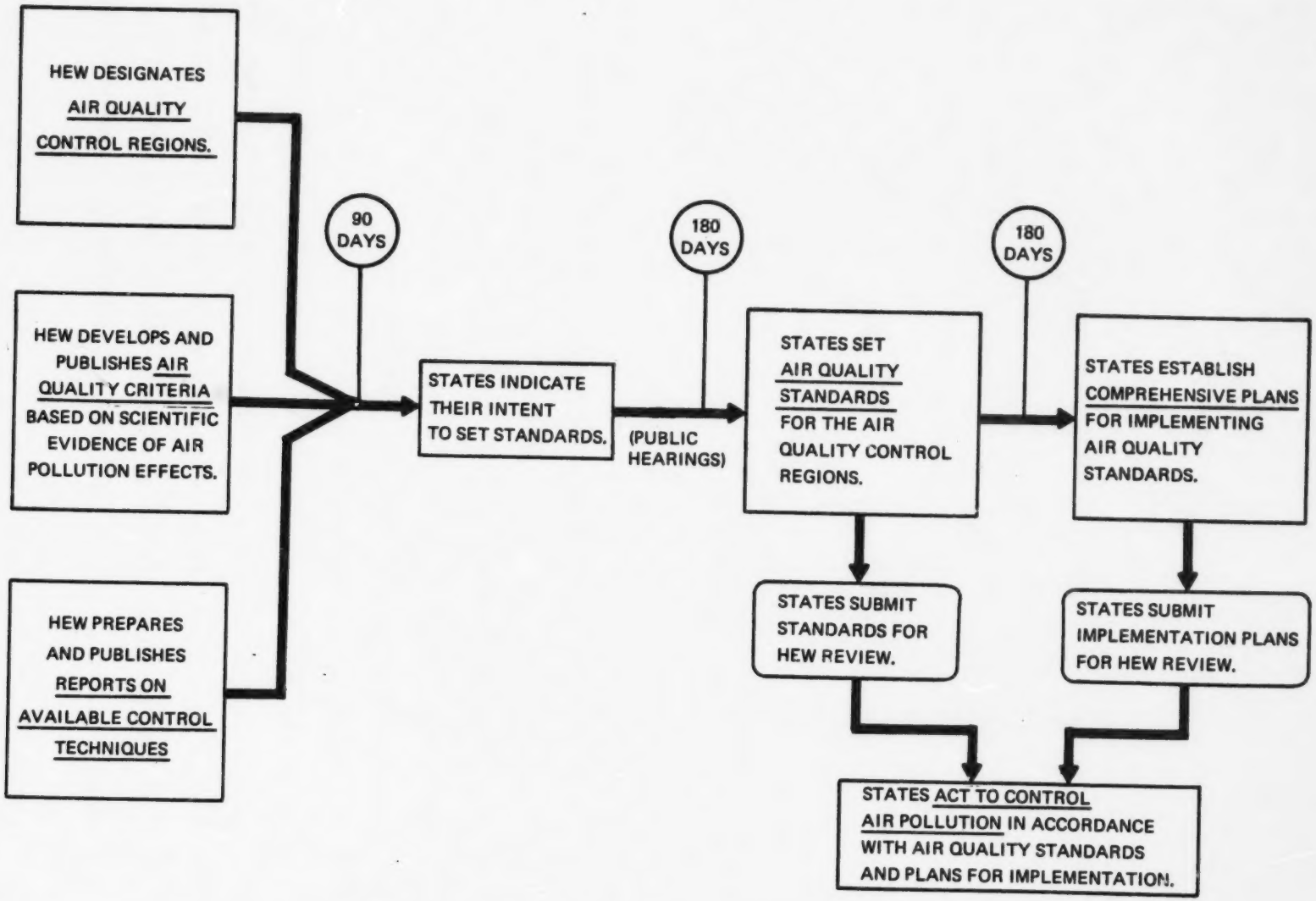
HEW DESIGNATES AIR QUALITY CONTROL REGIONS.
HEW DEVELOPS AND PUBLISHES AIR QUALITY CRITERIA BASED ON SCIENTIFIC EVIDENCE OF AIR POLLUTION EFFECTS.
HEW PREPARES AND PUBLISHES REPORTS ON AVAILABLE CONTROL TECHNIQUES
90 DAYS
STATES INDICATE THEIR INTENT TO SET STANDARDS.
180 DAYS
(PUBLIC HEARINGS)
STATES SET AIR QUALITY STANDARDS FOR THE AIR QUALITY CONTROL REGIONS.
180 DAYS
STATES ESTABLISH COMPREHENSIVE PLANS FOR IMPLEMENTING AIR QUALITY STANDARDS.
STATES SUBMIT STANDARDS FOR HEW REVIEW.
STATES SUBMIT IMPLEMENTATION PLANS FOR HEW REVIEW.
STATES ACT TO CONTROL AIR POLLUTION IN ACCORDANCE WITH AIR QUALITY STANDARDS AND PLANS FOR IMPLEMENTATION.

Figure 1 FLOW DIAGRAM FOR ACTION TO CONTROL AIR POLLUTION ON A REGIONAL BASIS, UNDER THE AIR QUALITY ACT.

technology and associated costs, the Governors of the States must file with the Secretary within 90 days a letter of intent, indicating that the States will adopt within 180 days ambient air quality standards for the pollutants covered by the published criteria and control technology documents and adopt within an additional 180 days plans for the implementation, maintenance, and enforcement of those standards in the designated air quality control region.

The new Federal legislation provides for a regional attack on air pollution and, at the same time, allows latitude in the form which regional efforts may take. While the Secretary retains approval authority, the States involved in a designated region assume the responsibility for developing standards and an implementation plan which includes administrative procedures for abatement and control. Informal cooperative arrangements with proper safeguards may be adequate in some regions, whereas in others, more formal arrangements, such as interstate compacts, may be selected. The objective in each instance will be to provide effective mechanisms for control on a regional basis.

THE SIZE OF A REGION

Several objectives are important in determining how large an air quality control region should be. Basically, these objectives can be divided into three separate categories. First, a region should be self-contained with respect to air pollution sources and receptors. In other words, a region should include most of the important sources in the area as well as most of the people and property affected by

those sources. In this way, all the major elements of the regional problem will lie within one unified jurisdiction. Unfortunately, since air pollutants can travel long distances, it is impractical if not impossible to delineate regions which are completely self-contained. The air over a region will usually have at least trace amounts of pollutants from external sources. During episodic conditions, such contributions from external sources may even reach significant levels. Conversely, air pollution generated within a region and transported out of it can effect external receptors to some degree. It would be impractical and inefficient to make all air quality control regions large enough to encompass these low-level effects. The geographic extent of trace effects overestimates the true problem area which should be the focus of air pollution control efforts. Thus, the first objective, that a region be self-contained, becomes a question of relative magnitude and frequency. The dividing line between "important influence" and "trace effect" will be a matter of judgement. The judgement should be based on estimates of the impact a source has upon a region, and the level of pollution to which receptors are subjected. In this respect, annual and seasonal data on pollutant emissions and ambient air concentrations are a better measure of relative influence than short term data on episodic conditions.

The second general objective requires that region boundaries be designed to meet not only present conditions but also future conditions. In other words, the region should include areas where residential and industrial expansion are likely to create air pollution problems

in the foreseeable future. This objective requires careful consideration of existing metropolitan development plans, expected population growth, and projected industrial expansion. Such considerations should result in the designation of regions which will contain the sources and receptors of regional air pollution for a number of years to come. Of course, the region boundaries need not be permanently fixed, once designated. Boundaries should be reviewed periodically and altered when changing conditions warrant readjustment.

The third objective is that region boundaries should be compatible with and even foster unified and cooperative governmental administration of the air resource throughout the region. Air pollution is a regional problem which extends across several municipal, county, and even State boundaries. Clearly, the collaboration of several governmental jurisdictions is prerequisite to the solution of the problem. Therefore, the region should be delineated in a way which encourages regional cooperation among the various governmental bodies involved in air pollution control. In this regard, the existing pattern of governmental cooperation on the whole range of urban problems may become an important consideration. Certainly the pattern of cooperation among existing air pollution control programs is a relevant factor. In general, administrative considerations dictate that governmental jurisdictions should not be divided. Although it would be impractical to preserve State jurisdictions undivided, usually it is possible to preserve the unity of county governments by including or excluding them in their entirety. In certain instances, the county level of

government does not exist. In these instances city and town boundaries are followed in determining the region.

To the extent that any two of the above three objectives lead to incompatible conclusions concerning region boundaries, the region must represent a reasonable compromise. A region should represent the best way of satisfying the three objectives simultaneously.

PROCEDURE FOR DESIGNATION OF REGIONS

Figure 2 illustrates the procedures used by the National Air Pollution Control Administration for designating air quality control regions.

A preliminary delineation of the region is developed by bringing together two essentially separate studies --- the "Evaluation of Engineering Factors," and the "Evaluation of Urban Factors."

The "Evaluation of Engineering Factors" considers pollutant source locations and the geographic extent of significant pollutant concentrations in the ambient air. An inventory of air pollutant emissions determines the geographic location and quantities of the various pollutants emitted from the sources in a region. Major quantities of pollution are emitted by automobiles and industry, and from refuse disposal operations, power generation, and space heating. The subsequent effect of the pollution emitted into the atmosphere is determined by measuring ambient air quality. The air quality analysis presented in this report is divided into two major segments. The first part deals with the topography and meteorology of the area and measured air quality.

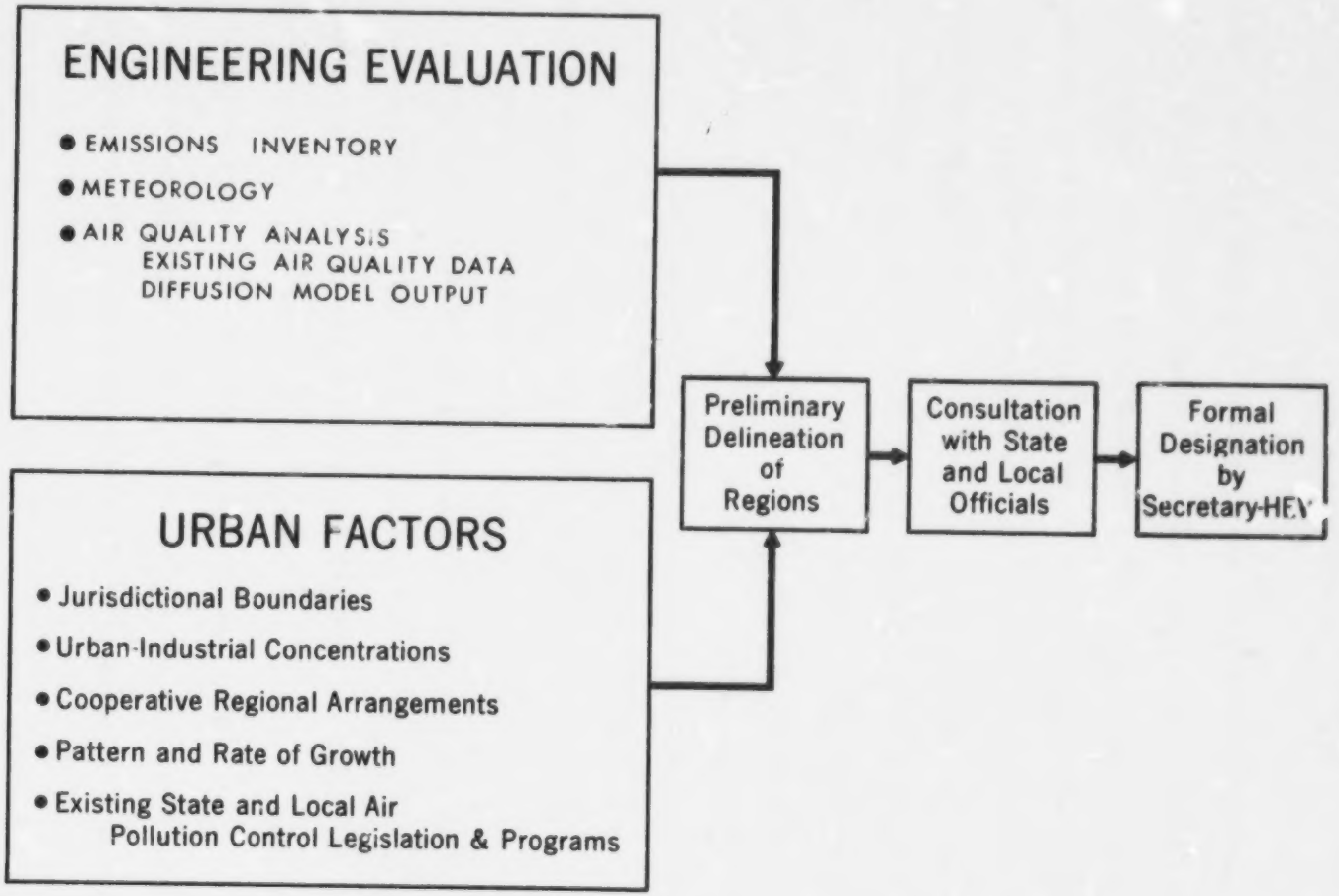

Figure 2. Flow diagram for the designation of air quality control regions.

This section deals with the topographical influences on local meteorological conditions and the subsequent meteorological effect on air quality. The second part of the analysis describes the results of the diffusion model applied to the Hartford-Springfield area in order to predict air quality. Some of the limitations of the model are also described. In addition, basic conclusions drawn from the model results, as they relate to the size of the proposed Region, are outlined.

The "Evaluation of Urban Factors" encompasses all considerations of a non-engineering nature. This evaluation consists of a review of existing governmental jurisdictions, current air pollution legislation and control programs, demographic data, current urbanization, and projected patterns of urbanization.

The findings of the engineering evaluation are combined with the results of the urban factors evaluation, and an initial proposal for the air quality control region is made. As indicated in Figure 2, the proposal is submitted for consultation with State and local officials. After reviewing the official transcript of the consultation proceedings which provides the viewpoints of State and local officials toward the proposal, the Secretary formally designates the region. Formal designation includes a notice in the Federal Register and a notification to the Governors of the States affected by the designation.

EVALUATION OF ENGINEERING FACTORS

EMISSION INVENTORY

A quantitative evaluation of air pollutant emissions provides the basic framework for air conservation activities. The compilation of an emissions inventory makes possible the correlation of pollutant emissions with specific geographic locations. This procedure generally results in the identification of the "core" of an air quality control region--that is, the area where the bulk of the pollutant emissions occur. In this study, the emissions inventory results are further utilized as input data to a meteorological diffusion model. In this manner the spatial and temporal distribution of the pollution emitted into the atmosphere can be systematically predicted. For these reasons, a presentation of the emissions inventory results serves as a logical starting point in the engineering evaluation.

The emission inventory was conducted by the Division of Air Quality and Emission Data of the National Air Pollution Control Administration. The emissions inventory included the Springfield-Chicopee-Holyoke, Hartford, New Britain, Waterbury, Meriden and New Haven Standard Metropolitan Statistical Areas as well as additional towns surrounding those SMSA's in Connecticut. The total study area, encompassing 2550 square miles, contains the bulk of the population and urbanization in central Connecticut and in the Lower Pioneer Valley. The estimated 1968 population for the survey area is 2,239,000 persons, with 1,916,000 persons residing in the six SMSA's*. Intense urbanization exists in a continuous

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*Figure 14 provides a population breakdown by individual SMSA's.

or near-continuous broad belt from north of Springfield to Hartford and south to include Waterbury, New Britain, and New Haven.

The Public Health Service rapid survey technique was used, with some modification, for the estimation of pollutant emissions.[1] The emissions were calculated from data representative of the year 1967 using Public Health Service emission factors.[2] Table I provides a breakdown of sulfur dioxide*, total particulate and carbon monoxide emissions by State and by SMSA according to source type in four general categories. These categories are transportation, fuel combustion in stationary sources, refuse disposal and industrial process emissions. Both States and all sub-areas within Connecticut contribute significant amounts of SO_2, CO and total particulate emissions for most source types with the exception of aircraft emissions and emissions from power plants.

Geographic source locations over the survey area are defined by the use of grid coordinates based on the Universal Transverse Mercator (UTM) System. Figure 3 shows a map of the survey area subdivided into cities and towns. Figure 4 shows the numbered grid system superimposed over an outline of the survey area. Grid squares 5 kilometers on a side are used in areas of most dense population and industrialization. Grid squares 10 kilometers on a side are used in areas of less dense urbanization.

Figure 5 shows the location of most major point sources. Point sources are concentrated in or close to Springfield, Hartford, Waterbury, and New Haven. Most power plants in the area are located alongside the Connecticut River. Two major power plants located in Bridgeport have also

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*Estimates are based on all oxides of sulfur, of which the vast majority is composed of SO_2.

TABLE 1. SUMMARY OF AIR POLLUTANT EMISSIONS IN THE HARTFORD-SPRINGFIELD INTERSTATE STUDY AREA, 1967 (TONS/YEAR).

		TRANSPORTATION			COMBUSTION OF FUELS, STATIONARY SOURCES				SOLID WASTE DISPOSAL		INDUSTRIAL PROCESS EMISSIONS
		Gasoline	Diesel	Aircraft	Industry	Steam-Electric	Residential	Other	Incineration	Open Burning	
Sulfur Dioxide	Massachusetts Total	590	490	0	15,900	43,100	4,500	7,700	130	0	Neg.
	Connecticut Total	2,360	690	Neg.	59,600	174,600	16,300	28,900	430	Neg.	1,500
	Hartford SMSA	820	240	Neg.	18,190	16,480	5,040	9,980	190	Neg.	Neg.
	Meriden SMSA	40	20	0	2,440	0	490	920	Neg.	Neg.	Neg.
	New Britain SMSA	170	50	0	5,100	0	1,500	2,340	30	0	Neg.
	New Haven SMSA	580	170	0	12,740	10,780	2,970	5,630	130	0	130
	Waterbury SMSA	250	70	0	10,050	0	1,510	3,430	30	0	1,260
	Remainder of Conn. Study Area	470	140	0	11,090	147,300	4,780	6,610	40	0	120
Total Particulates	Massachusetts Total	790	1,360	76	2,200	8,640	1,500	1,040	840	1,150	640
	Connecticut Total	3,140	1,900	340	7,110	5,330	4,070	2,970	4,090	3,260	4,690
	Hartford SMSA	1,090	660	340	1,130	690	1,120	1,090	2,040	1,260	680
	Meriden SMSA	100	60	0	190	0	120	70	Neg.	Neg.	Neg.
	New Britain SMSA	220	130	0	400	0	560	190	270	1,080	610
	New Haven SMSA	770	470	0	890	270	710	2,580	1,160	240	480
	Waterbury SMSA	330	200	0	3,760	0	370	410	290	330	940
	Remainder of Conn. Study Area	630	380	0	740	4,370	1,190	500	320	350	1,990
Carbon Monoxide	Massachusetts Total	125,800	740	3,850	230	270	1,400	460	4,790	6,120	6,400
	Connecticut Total	656,250	1,040	3,070	380	550	3,270	1,220	7,510	16,200	5,900
	Hartford SMSA	228,300	360	3,070	100	10	740	520	6,540	6,580	2,600
	Meriden SMSA	19,900	30	0	10	0	100	10	Neg.	Neg.	Neg.
	New Britain SMSA	46,400	70	0	30	0	590	30	20	5,340	750
	New Haven SMSA	160,600	260	0	70	1	530	990	910	1,080	630
	Waterbury SMSA	69,400	110	0	130	0	270	210	20	1,660	1,880
	Remainder of Conn. Study Area	131,700	210	0	40	540	1,030	60	20	1,500	50

FIGURE 3. EMISSION INVENTORY SURVEY AREA.

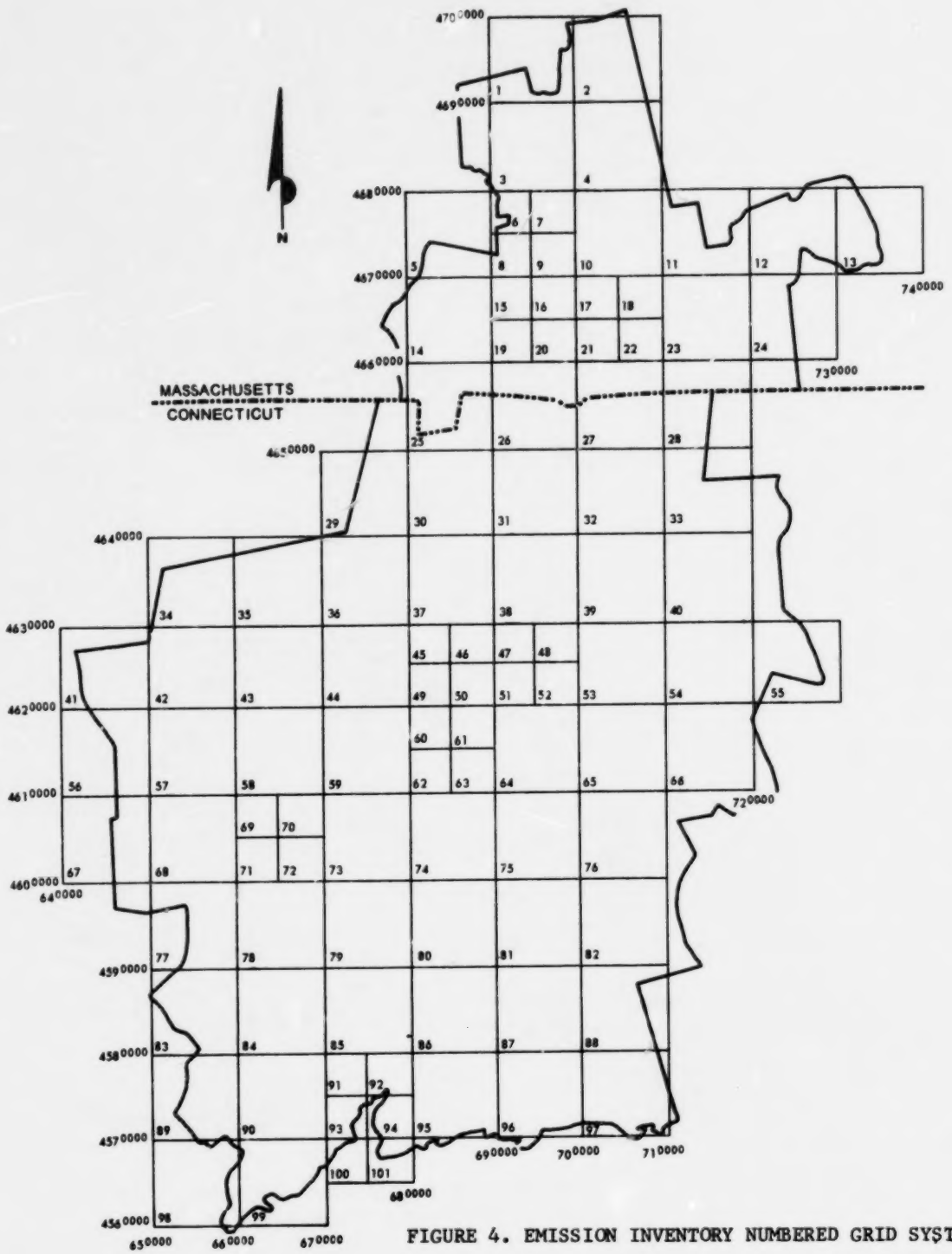

FIGURE 4. EMISSION INVENTORY NUMBERED GRID SYSTEM.

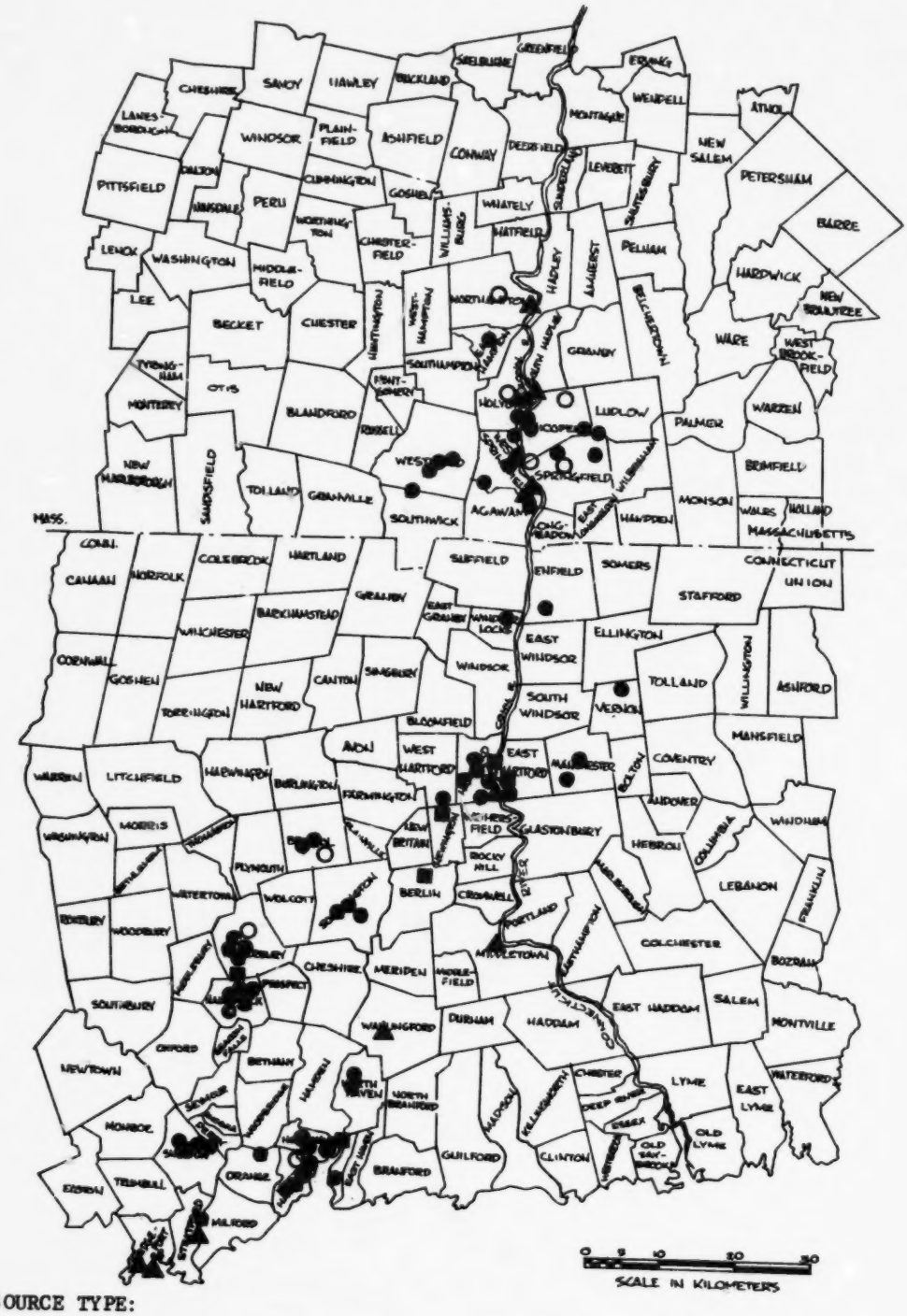

FIGURE 5. LOCATION OF MAJOR POINT SOURCES.

been included in the emissions survey.

Figures 6, 7, and 8 are emission density maps for SO_2, CO, and total particulates, respectively, based on the grid system. The density maps are constructed according to yearly average daily emissions for each pollutant. The densities are computed on the basis of emissions from both point sources and area sources within each grid zone. The majority of the SO_2 emissions are attributable to power plants in the survey area, while industrial sources are also substantial contributors. The pattern of SO_2 emissions (Figure 6) follows closely the pattern of urbanization in the survey area as well as the pattern of power plant and industrial point source locations. Carbon monoxide emissions are primarily attributable to motor vehicles; thus, Figure 7 provides an indication of the vehicular traffic density distribution over the survey area. As expected, the more heavily populated areas (Springfield, Hartford, New Haven) produce the greatest CO emissions. All source types contribute significant amounts of total particulate emissions. The total particulate emission density map (Figure 8) reflects the pattern of urbanization over the study area since the source types themselves are an integral part of the urban pattern.

A State-wide emission inventory was conducted by the Travelers Research Center, Inc., (TRC) as part of a report[3] to the Connecticut Research Commission on the Connecticut air pollution problem. The results of the TRC inventory tend to validate the findings of the NAPCA source survey, particularly in reference to the geographic distribution of emissions. The TRC survey indicated that the winter pattern of SO_2

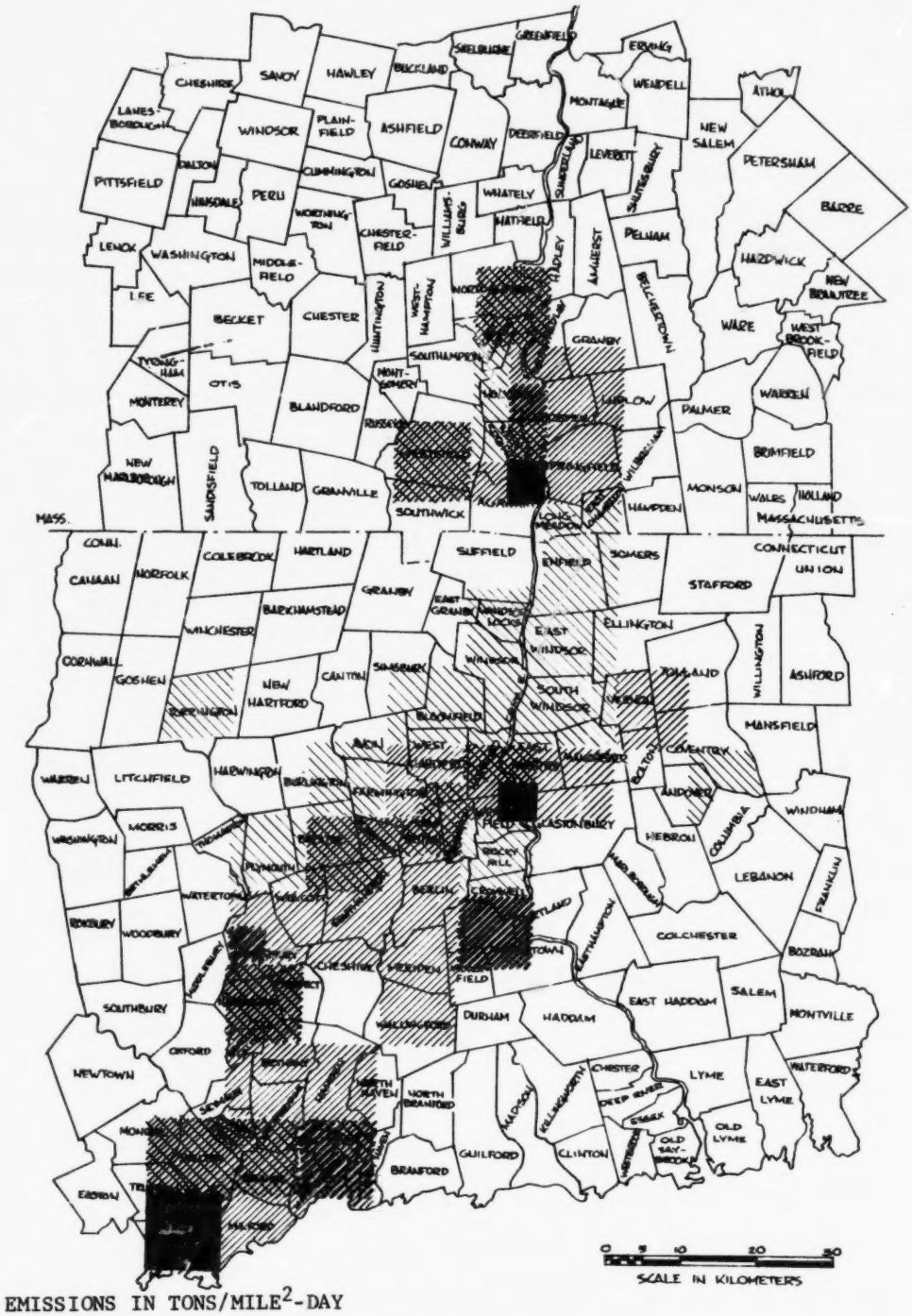

FIGURE 6. SULFUR DIOXIDE EMISSION DENSITIES.

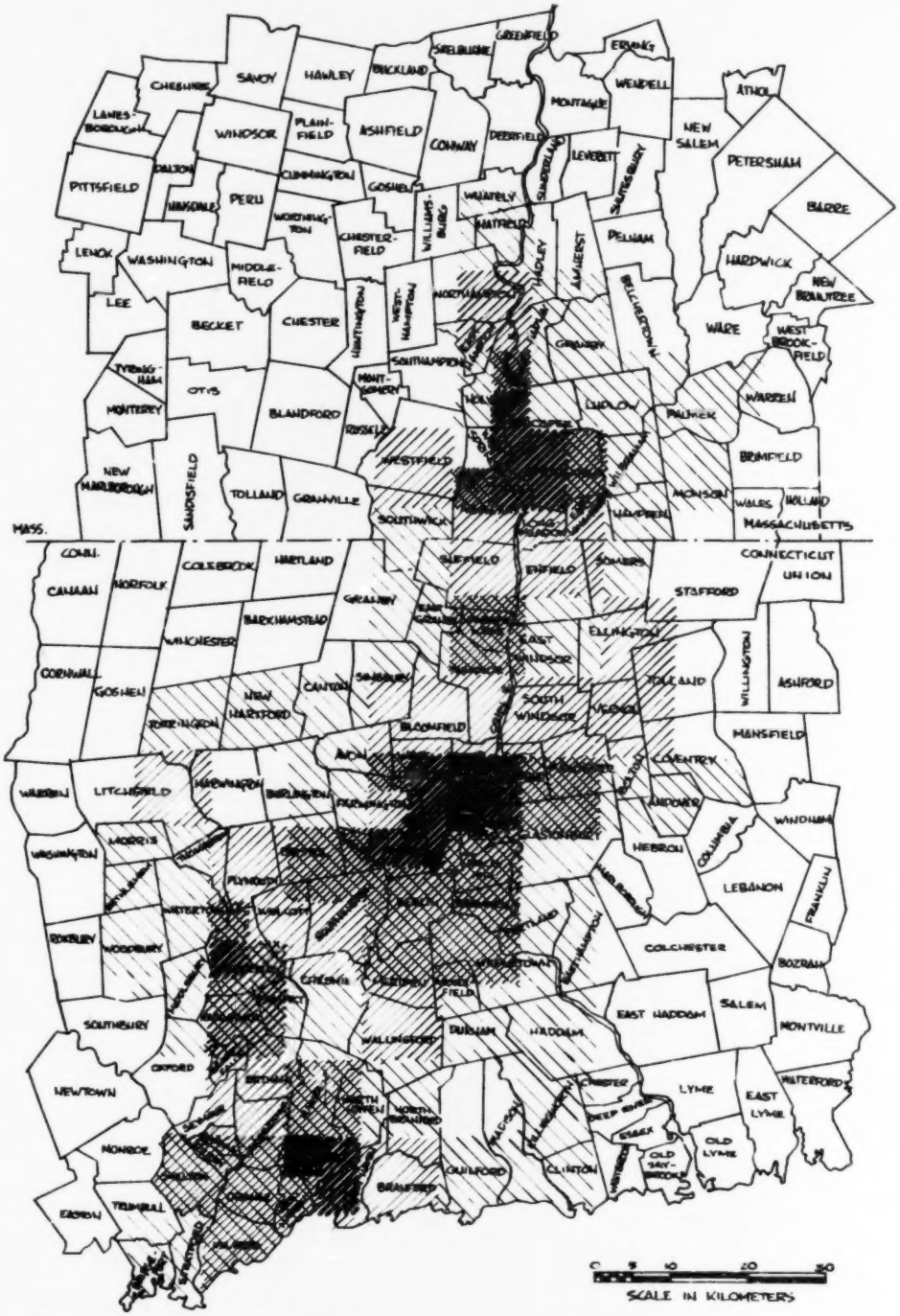

FIGURE 7. CARBON MONOXIDE EMISSION DENSITIES.

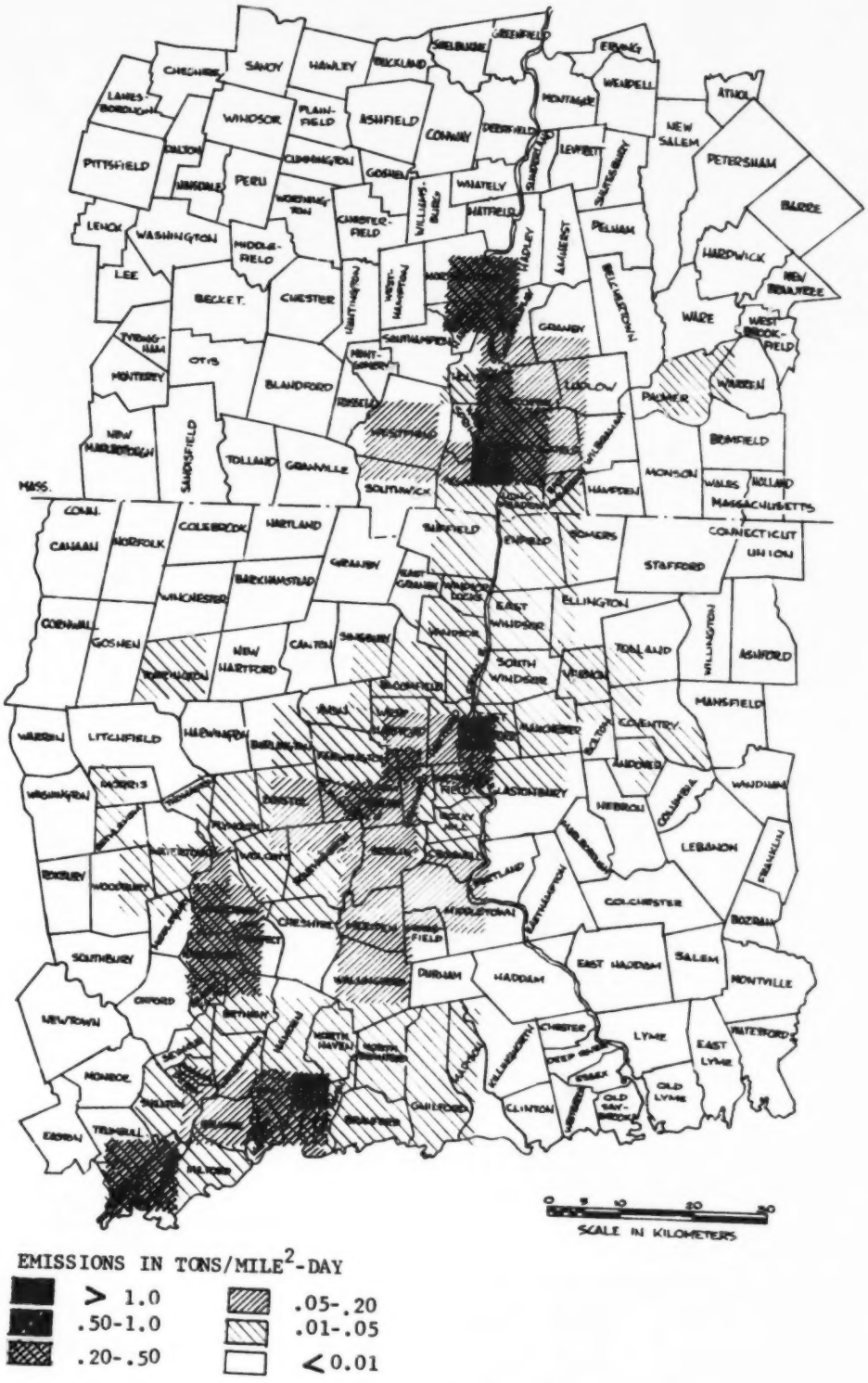

FIGURE 8. TOTAL PARTICULATE EMISSION DENSITIES.

emissions extends from the Massachusetts-Connecticut State boundary south along the Connecticut River to Middletown. This pattern of relatively high SO_2 emissions extends eastward from the Connecticut River to Tolland and Hebron and westward to Simsbury and Bristol. Relatively high emissions occur in the New Haven area, and in areas north to and including Meriden. Waterbury and towns to the south of it along the Naugatuck Valley were found to be areas of relatively high emissions. Geographic patterns of relatively high suspended particulate emissions were similar to those for SO_2. The pattern of CO emissions reflected the existence of major highways in the area.

AIR QUALITY ANALYSIS

Introduction

To facilitate an air resource management program, an air quality control region should include those jurisdictions containing the majority of air pollutant sources within an urban area. The air quality control region should also include those jurisdictions containing the majority of the people and property adversely affected by the source emissions. The core area of a region can be roughly defined on the basis of pollutant point source locations and relative emission densities. However, ambient air quality analysis is necessary in order that the peripheral pollutant receptor areas may be identified and subsequently included in the air quality control region. This procedure results in an essentially self-contained region, in that it will include within its bounds virtually the entire source-receptor system for a particular area. In this way, too, the possibility of pollutant cross-boundary transport problems will be minimized.

Two alternate approaches have been used to provide an indication of air quality in the Hartford-Springfield study area*. The first and most logical approach for the determination of air quality is to measure quantitatively pollutant concentrations in the ambient air. For the purposes of this report, a review of existing air quality data was made. The second approach consists of predicting air quality over the Region. This has been done by the use of a meteorological diffusion model. This technique was particularly desirable in the study area since existing air sampling networks do not encompass large enough areas so that they may be used as guides to the establishment of the exact outer limits of the Region.

Topography, Meteorology, and Measured Air Quality

The Hartford-Springfield area lies in the south portion of the upland region of New England. Its surface is, in general, that of a gently undulating upland divided by the lowland of the Connecticut River Valley. Between the upland and the sea lies a relatively narrow strip of lowland known as the "seaboard lowland." The Connecticut River Valley varies in width from approximately 5 to 20 miles. Adjacent to the Connecticut River the land is low and level or rolling. However, there are ridges of traprock which rise several hundred feet above the valley floor. The range of hills forming the boundaries of the valley rise 400 to 600 feet above the valley floor.

The study area is frequented by extensive winter storm activity and a day-to-day variability of local weather. During the winter, northerly

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*The term "study area" will be used to define the approximate area over which the emissions inventory was conducted.

winds are predominant, while southerly winds are predominant during the summer (see Figure A-1). Surface-level winds in the Connecticut Valley are markedly from a northerly or southerly direction, and are infrequently from the east or west. This is due to the general broadscale features of the winds over the region and due, more specifically, to the orientation of the hills which form the valley sides. The effect of the hills, which lie mainly in a north-south direction, is to deflect winds up or down the valley.

Air sampling in the Springfield area is conducted by the Lower Pioneer Valley Air Pollution Control District. Routine sampling of sulfur oxides, suspended particulates, and settleable particulates is conducted. Suspended particulate sampling sites are located in South Hadley, Holyoke, Chicopee, Springfield, West Springfield, Westfield, and Agawam. Sampling from August 196[illegible] to July 1966 indicated that highest yearly average suspended particulate concentrations occurred in Holyoke (139 $\mu g/m^3$) and Springfield (136 $\mu g/m^3$). Another station located in Springfield measured a low yearly average concentration of 74 $\mu g/m^3$. Winter average concentrations were generally greater than annual averages, while summer averages were lowest. A yearly average concentration for all 12 sampling sites was 106 $\mu g/m^3$ and was 100 $\mu g/m^3$ averaged for four sites in Springfield. The average concentrations for urban sampling sites exceeded those at non-urban sites by a significant amount. Both urban and non-urban values, however, are above typical background levels recorded at non-urban sites in neighboring States.[4]

A more extensive 21 station network measures settleable particulates through the use of dustfall buckets. The 1965-66 yearly average dustfall was 17 tons/mi.^{2}-month. Holyoke had the highest city average (3 sites)

of 22 tons/mi.^{2}-month followed by Springfield with 19 tons/mi.^{2}-month (5 station average).

Complete SO_2 sampling data exists for the City of Springfield for the year 1968. Greatest measured concentrations occurred during the winter months (.182 ppm January average), and were lowest during the summer (.034 ppm June average). The 1968 yearly average SO_2 concentration for Springfield was .068 ppm.

The Connecticut Air Sampling Network is operated by the State Department of Health with monitoring for SO_2, sulfation rate and settleable and suspended particulates. Measured suspended particulate concentrations in the major cities in central Connecticut for the year 1967 were greater than typical non-urban or background levels measured in other sections of the northeast United States[4]. Hartford and Naugatuck had yearly mean concentrations of 90 $\mu g/m^3$, while New Haven (86 $\mu g/m^3$), Waterbury (79 $\mu g/m^3$), Torrington (57 $\mu g/m^3$), and Middletown (49 $\mu g/m^3$) had lower measured concentrations. These measured values appear to bear little relation to community size. It is probably safe to assume that concentrations substantially above the natural background level occur throughout the urbanized portions of central Connecticut connecting these major cities. Settleable particulate levels, while showing wide variability in values from the years 1966 to 1968, reflect the existence of significant amounts of dustfall in Hartford, New Britain, New Haven, Naugatuck, Waterbury and Torrington.

Sampling for the gaseous pollutants, SO_2 and CO, has been limited in Connecticut. Average SO_2 concentrations for the first half of 1968 were

.05 ppm in Hartford and .06 ppm in New Haven*. A study of SO_2 pollution in the Hartford area[5] indicated that greatest concentrations occurred in the winter, and were particularly high in Hartford and New Britain. These measurements for the yearly average SO_2 concentration in Hartford (over a period from 1966-1967) were comparable to concentrations recorded by the State Department of Health. SO_2 measurements in Middletown[6] indicated an average concentration of .022 ppm during the winter of 1965-1966. Carbon monoxide sampling[5] in the City of Hartford resulted in a 1967 winter average value of 2.7 ppm and a 1.9 ppm summer average. A sampling site located in East Windsor measured concentrations of .9 ppm and .7 ppm for the winter and summer averaging periods, respectively.

Diffusion Model Results

A meteorological diffusion model has been used to estimate suspended particulates, sulfur dioxide and carbon monoxide concentrations in the ambient air at specified ground-level receptor points. The model predicts these concentrations from the mathematical treatment of pollutant emissions and meteorological data**. While inherent limitations in the model are recognized, its value lies in providing reasonable spatial distributions of long term (seasonal and annual)*** average pollutant concentrations.

Figure 9 shows theoretical suspended particulate concentrations in

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*Connecticut State Department of Health measurements.

**See Appendix A for a more detailed discussion.

***Averaging times are as follows:

Winter: December, January, and February
Summer: June, July, and August
Annual: All 12 months of the year

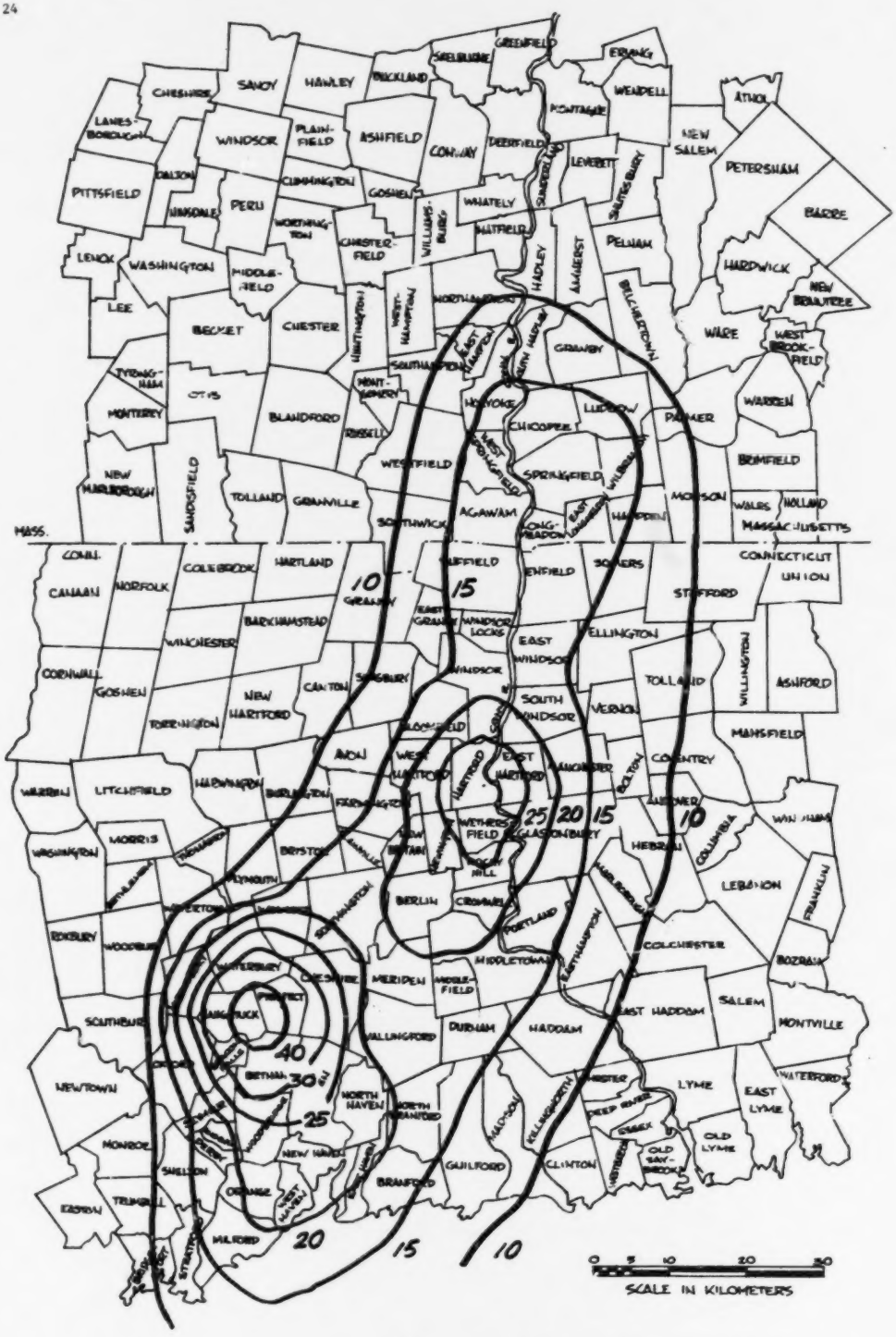


FIGURE 9. THEORETICAL SUSPENDED PARTICULATE CONCENTRATIONS IN $\mu G/M^3$; WINTER AVERAGE.

$\mu g/m^3$ for the winter averaging period. It is during this time that emissions are the greatest and that particulate pollution build-up (a result of meteorological conditions during the winter averaging time), as predicted by the model, is greatest. This fact has been confirmed from actual air quality data. As a result, a greater land area is affected by any specific concentration contour.

The predicted concentrations shown in Fugure 9 should not be considered absolute since they do not conform closely in magnitude to measured concentrations. However, the pollutant distribution pattern indicates relatively high suspended particulate concentrations centered on Hartford and Naugatuck. The overall diffusion pattern reflects the existence of an urbanized corridor stretching from New Haven northeast to Hartford and then along the Connecticut River to Holyoke and Northampton. The influence of inventoried emissions appears to affect equally the air quality over a peripheral area (at the 10 $\mu g/m^3$ isopleth) extending north to Hadley, east to Monson, Tolland and East Haddam, and west to Westfield, Burlington, and Woodbury.

Theoretical sulfur dioxide concentrations are shown in Figure 10. Results for the winter averaging period are presented since any given concentration contour predicted by the model affects the greatest land area during that period. A 3-hour half-life for SO_2 has been assumed as the rate of decay of sulfur dioxide. This procedure has been found to result in the most reasonable predicted concentrations. In general, the model underestimates measured concentrations. Highest predicted concentrations occur centered over Springfield, Middletown and Milford. The 0.01 concentration contour appears to enclose substantially the same

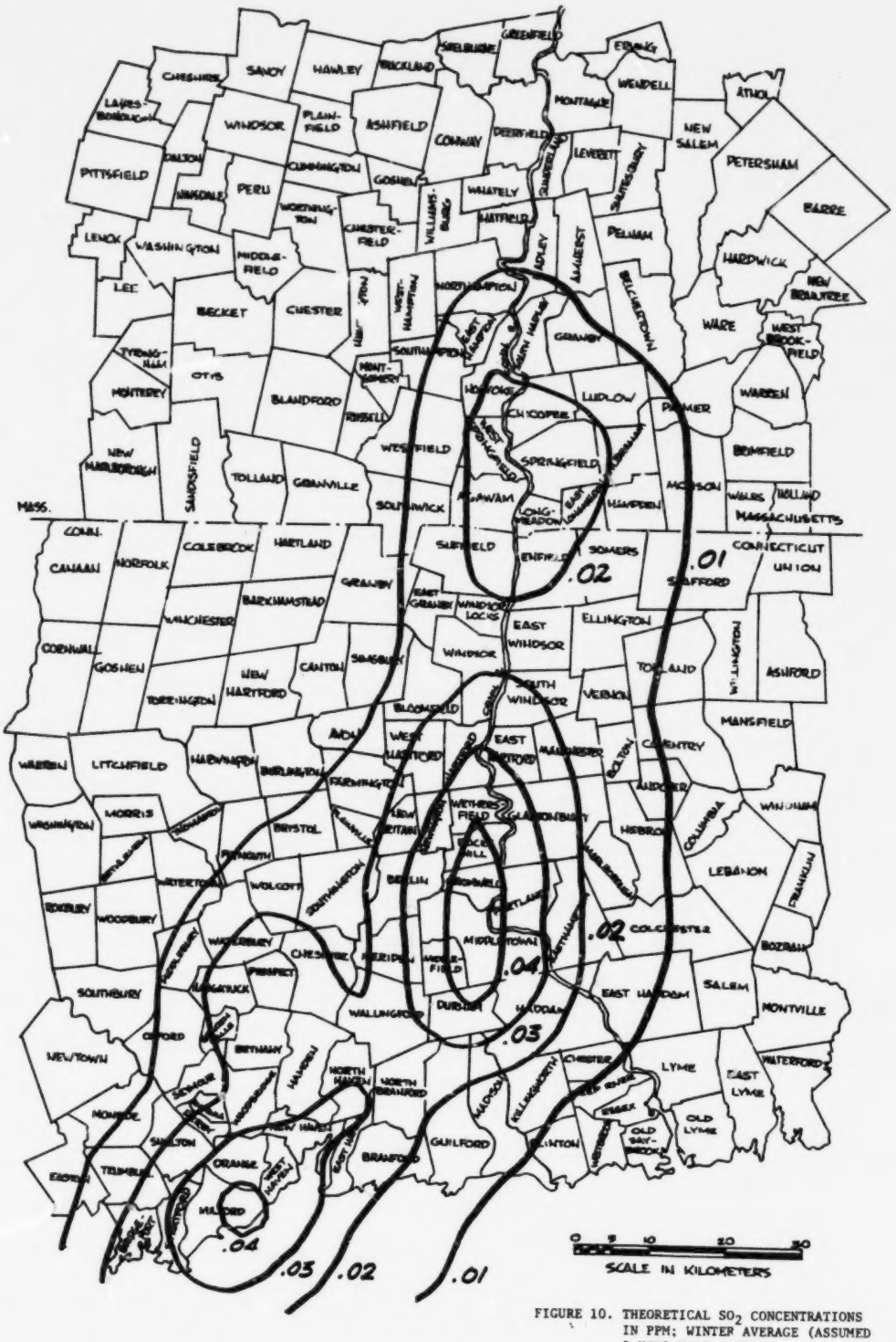


FIGURE 10. THEORETICAL SO_2 CONCENTRATIONS IN PPM; WINTER AVERAGE (ASSUMED 3 HOUR HALF-LIFE).

area as does the 10 $\mu g/m^3$ suspended particulate isopleth, as outlined previously. The pattern of the isopleths again reflects the urban pattern of central Connecticut and metropolitan Springfield, and can also be correlated with the pattern of emissions over the study area (see Figure 6).

Predicted summer CO levels are shown in Figure 11. Greatest emissions occur during this period, and greatest concentrations in the ambient air are predicted by the model. Limited air quality data does not confirm this, however, since measurements at two sampling sites revealed greatest CO concentrations during the winter (see page 23). Past application of the diffusion model has shown that CO concentrations tend to be underestimated. Comparison with the limited data from the Hartford area indicates that this is true of the results shown in Figure 11 as well. The area enclosed by the .15 ppm contour appears to be that most significantly affected by the inventoried source emissions. Beyond that contour the concentration gradient decreases significantly.

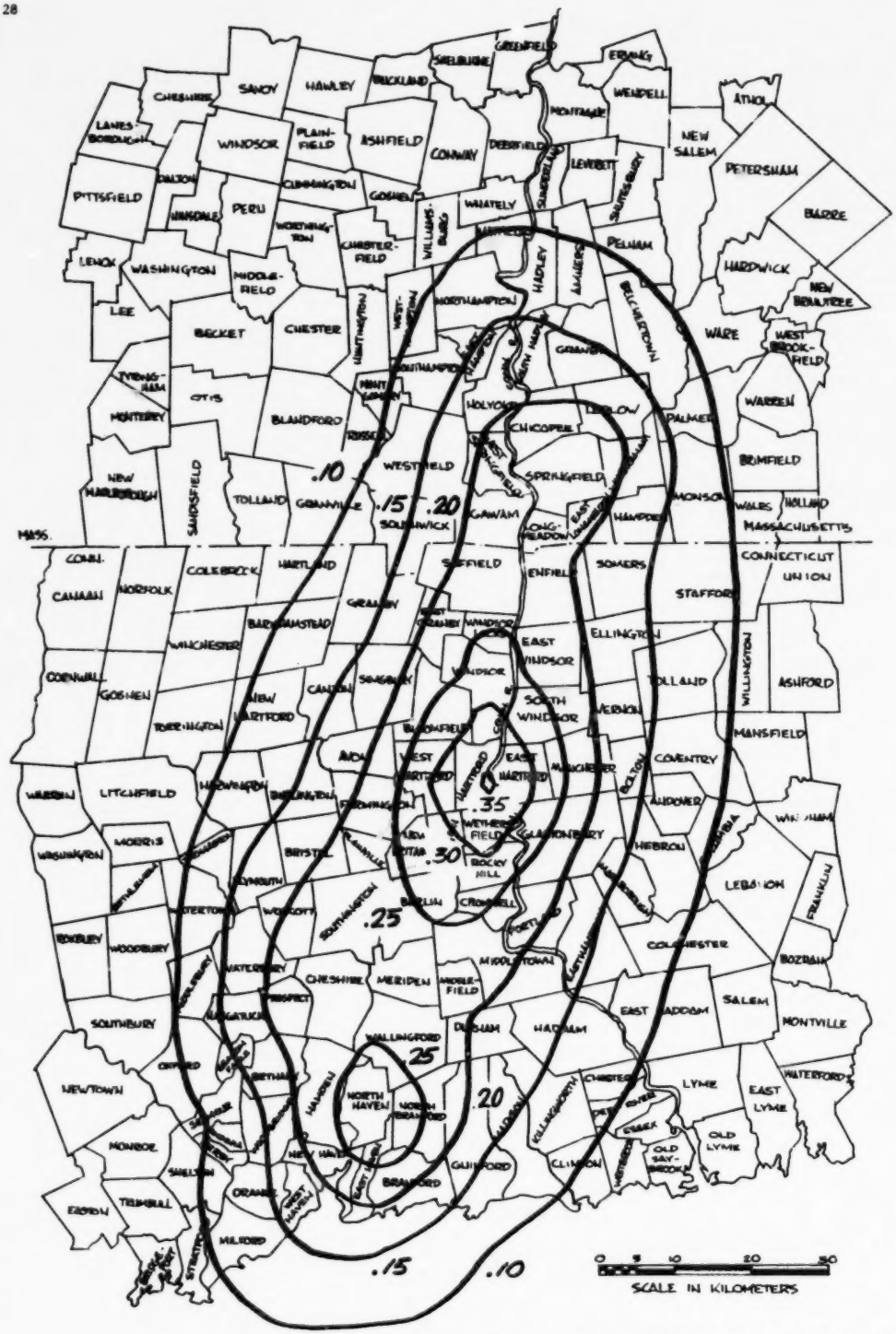


FIGURE 11. THEORETICAL CARBON MONOXIDE CONCENTRATIONS IN PPM; SUMMER AVERAGE.

EVALUATION OF URBAN FACTORS

INTRODUCTION

The Air Quality Act of 1967 calls for the designation of air quality control regions based on "jurisdictional boundaries, urban-industrial concentrations, and other factors" in order to provide for the adequate implementation of air quality standards. The designation of air quality control regions must also be based on a consideration of existing cooperative regional arrangements, State and local air pollution control programs and enabling legislation, and patterns and rates of urban growth.

POPULATION DISTRIBUTION

Existing and potential air pollution problems can be related geographically to areas subject to present or anticipated residential and industrial development. Similarly, air pollution problem areas can generally be identified by studying population statistics since human activity is the basic cause of air pollution. Figure 12 shows 1965 population distribution by Planning Regions (See Figure 15) in Connecticut and by County in Massachusetts. The population density values are in persons per square mile. In Massachusetts, existing population is generally concentrated along the Connecticut River. The cities of Springfield, Chicopee and Holyoke contain the most dense population in the Massachusetts portion of the study area. In Connecticut, a continuous band of densely populated cities and towns stretches from the Connecticut-Massachusetts State line south along the Connecticut River to Middletown. High density areas also extend eastward from the Connecticut River to Vernon and westward to Bristol, Watertown and Waterbury. Also, a band of high-density population extends on a northeast-southwest axis from Meriden to New Haven.

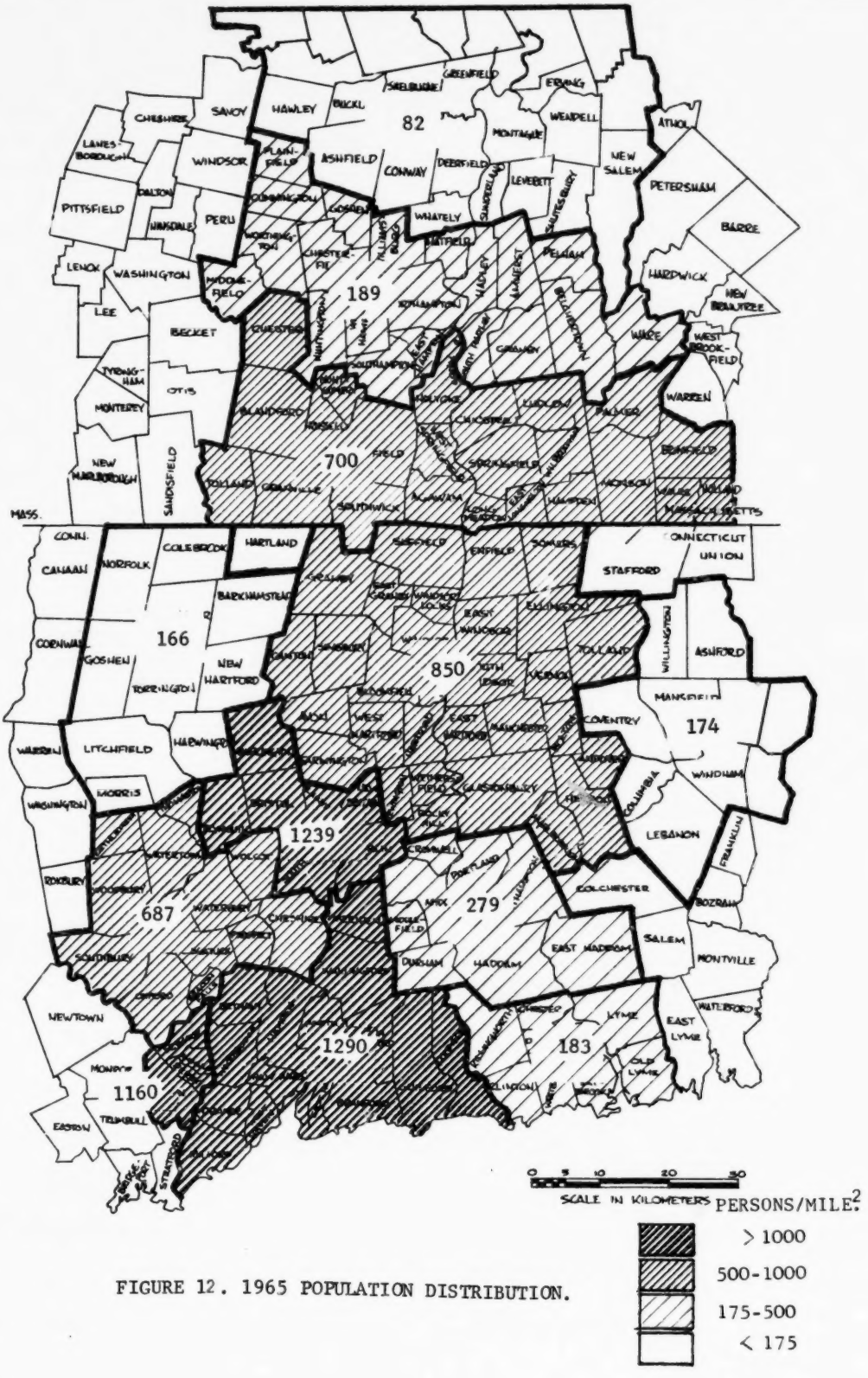


FIGURE 12. 1965 POPULATION DISTRIBUTION.

Figure 13 shows 1980 projected population densities (persons per square mile) by Planning Region in Connecticut. Also shown are 1980 projected population densities for major portions of Hampden and Hampshire Counties in Massachusetts. Population statistics for the Connecticut Planning Regions shown in Figures 12 and 13 indicate an increase in total population from 1,859,000 persons in 1965 to approximately 2,400,000 persons by 1980. Greatest absolute growth will occur in the Capitol Planning Region while greatest growth in terms of additional residents per square mile will occur in the South Central Connecticut Planning Region. The Central Connecticut Planning Region will also experience a high increase in growth in terms of additional residents per square mile. Table II presents the absolute population statistics for 1965 and 1980 from which the density values in Figures 12 and 13 were computed.

In Massachusetts, Hampden County will experience the greatest absolute growth, followed by Hampshire County. Growth in Franklin County is likely to remain low in terms of both absolute and per cent rate of increases, although no figures are available to confirm this. The population distribution in Hampden County will change somewhat as growth occurs outside the major cities in the presently sparsely populated areas. Thus the population of the central cities (Springfield, Chicopee and Holyoke) will decline in importance in relation to the total population of Hampden County.

INDUSTRY

Manufacturing is the predominant income producing component of the Springfield metropolitan area, though industrial land use comprises a very small percentage of the developed land in that area. The existing industrial land use pattern is concentrated in the urban core area (Springfield and Chicopee) though it is likely that the scarcity of suitable industrial

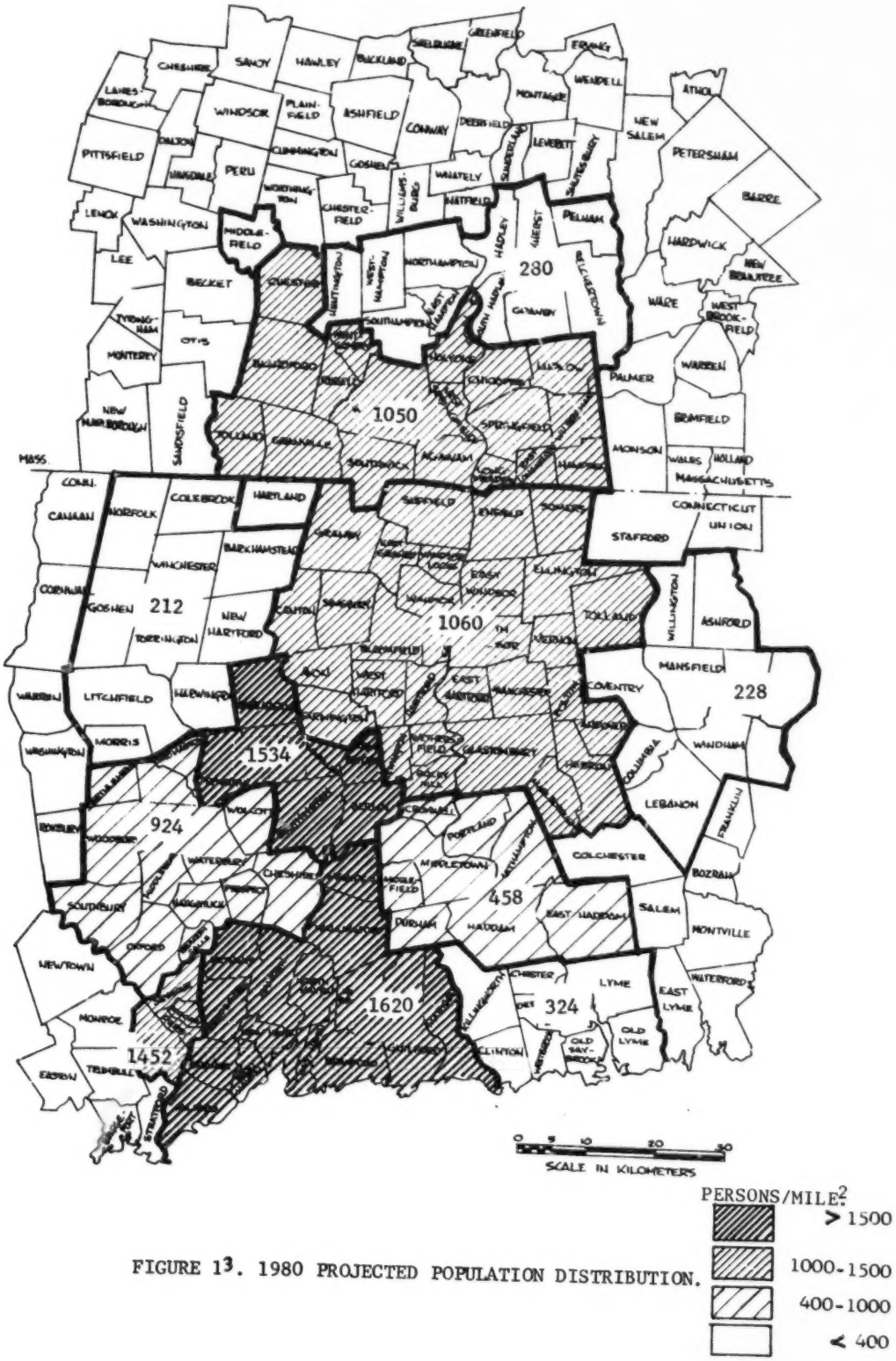


FIGURE 13. 1980 PROJECTED POPULATION DISTRIBUTION.

TABLE II. PRESENT AND PROJECTED POPULATION BY JURISDICTION

JURISDICTION	AREA ($Mi.^2$)	1965 POPULATION	1965 POPULATION DENSITY (PERSONS/$Mi.^2$)	1980 PROJECTED POPULATION	1980 PROJECTED POPULATION DENSITY (PERSONS/$Mi.^2$)	ADDITIONAL RESIDENTS PER SQUARE MILE 1965-1980
CONN. PLANNING REGIONS						
CAPITOL	766	652,100	850	811,100	1060	210
MID-STATE	259	72,200	279	118,600	458	179
CENTRAL CONN.	167	206,300	1239	256,100	1534	295
CENTRAL NAUGATUCK VALLEY	313	215,400	687	289,500	924	237
VALLEY	57	65,700	1160	82,200	1452	292
S. CENTRAL CONN.	382	492,300	1290	617,400	1620	330
CONN. RIVER ESTUARY	191	35,000	183	61,900	324	141
WINDHAM	327	56,600	174	74,200	228	54
LITCHFIELD HILLS	382	63,330	166	80,900	212	46
MASS. COUNTIES						
HAMPDEN	622	435,300	700	506,000*	1050*	N.A.
HAMPSHIRE	529	100,100	189	89,300**	280**	N.A.
FRANKLIN	708	57,700	82	N.A.	N.A.	N.A.

N.A. : INFORMATION NOT AVAILABLE
* : ONLY 482 $Mi.^2$ OF COUNTY CONSIDERED
** : ONLY 280 $Mi.^2$ OF COUNTY CONSIDERED

sites in the core area will cause industry to gravitate to the fringes of the urban concentration. Statistics showing acres developed for industrial uses from 1955 to 1964 indicate that East Longmeadow experienced the greatest industrial site development. The stable industries in this region are paper and allied products, rubber and plastics, electrical machinery and primary metals, while the growing industries are chemicals, printing and publishing and scientific instruments.

Connecticut is one of the most highly industrialized States in the nation, and ranks second in the ratio of manufacturing employees to total non-agricultural employees (42%). Employment for manufacture of transportation equipment is greatest, followed by the manufacture of machinery, fabricated metals, electrical equipment, and primary metals. In central Connecticut, industrial activity, as measured by total manufacturing employment figures, is concentrated in Hartford (149,500 persons) and New Haven (113,800 persons) Counties. The combined area of the Capitol, Central Connecticut and Mid-State Planning Regions contains a greater amount of industrially zoned, but presently vacant, land than any other portion of the State. The availability of this prime industrial land can be expected to promote a significant future increase in industrial activities in central Connecticut. At the present time, the most important manufacturing towns in central Connecticut are East Hartford, Hartford, New Haven, Waterbury, New Britain, North Haven, Bristol, Windsor Locks, West Hartford, Meriden, and Naugatuck, in that order.

EXISTING REGIONAL ARRANGEMENTS

Figure 14 shows the boundaries and 1968 populations of the six Standard Metropolitan Statistical Areas (SMSA's) in central Connecticut and in Massachusetts. The core cities of these SMSA's are Springfield,

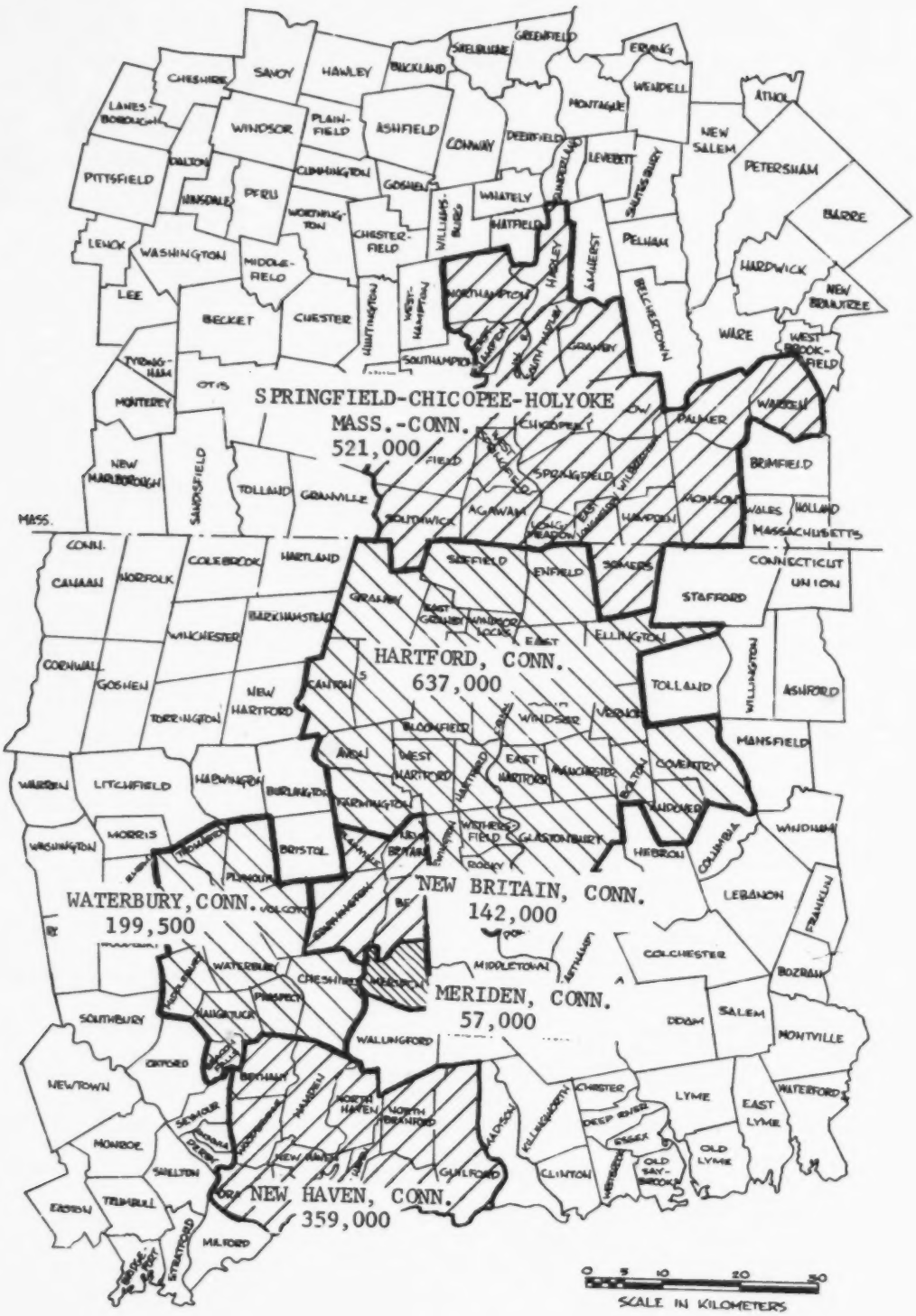


FIGURE 14. STANDARD METROPOLITAN STATISTICAL AREAS.

Hartford, New Britain, Meriden, Waterbury, and New Haven. The municipalities included in these SMSA's are those that are integrated socially and economically with the core cities, and with each other. The influence of the Springfield-Chicopee-Holyoke core extends north to Hadley, west to Westfield and east to Warren. The Hartford SMSA extends south to Cromwell, west to Canton and east to Ellington. Meriden town itself comprises an SMSA while the New Britain SMSA consists of four cities and towns.

In Connecticut, counties no longer function as political entities. Instead, Planning Regions have been defined by the Connecticut Development Commission as directed by State law. The boundaries of these Planning Regions are shown in Figure 15. The regional Planning Agencies operating in each of these Planning Regions are directed by statute to prepare and adopt regional development plans to provide a framework for local planning. In addition, their function is to act as a foundation for a continuing planning process in their respective Planning Regions. The Planning Agencies have no direct authority to enforce their recommendations or to require conformance by any municipality to their regional plans. The boundaries of these regions have been defined to include those municipalities whose social, cultural, and economic activities are oriented to a particular urban center. Thus, the Planning Regions would include the town or towns serving as an urban center and the surrounding municipalities where a clear inter-relationship between them is evident. The relationship of the peripheral towns to the urban core was evaluated on the basis of newspaper circulation patterns, commuting patterns of manufacturing workers, labor market areas, and so on.

Figure 15 indicates the extent of the Lower Pioneer Valley Regional

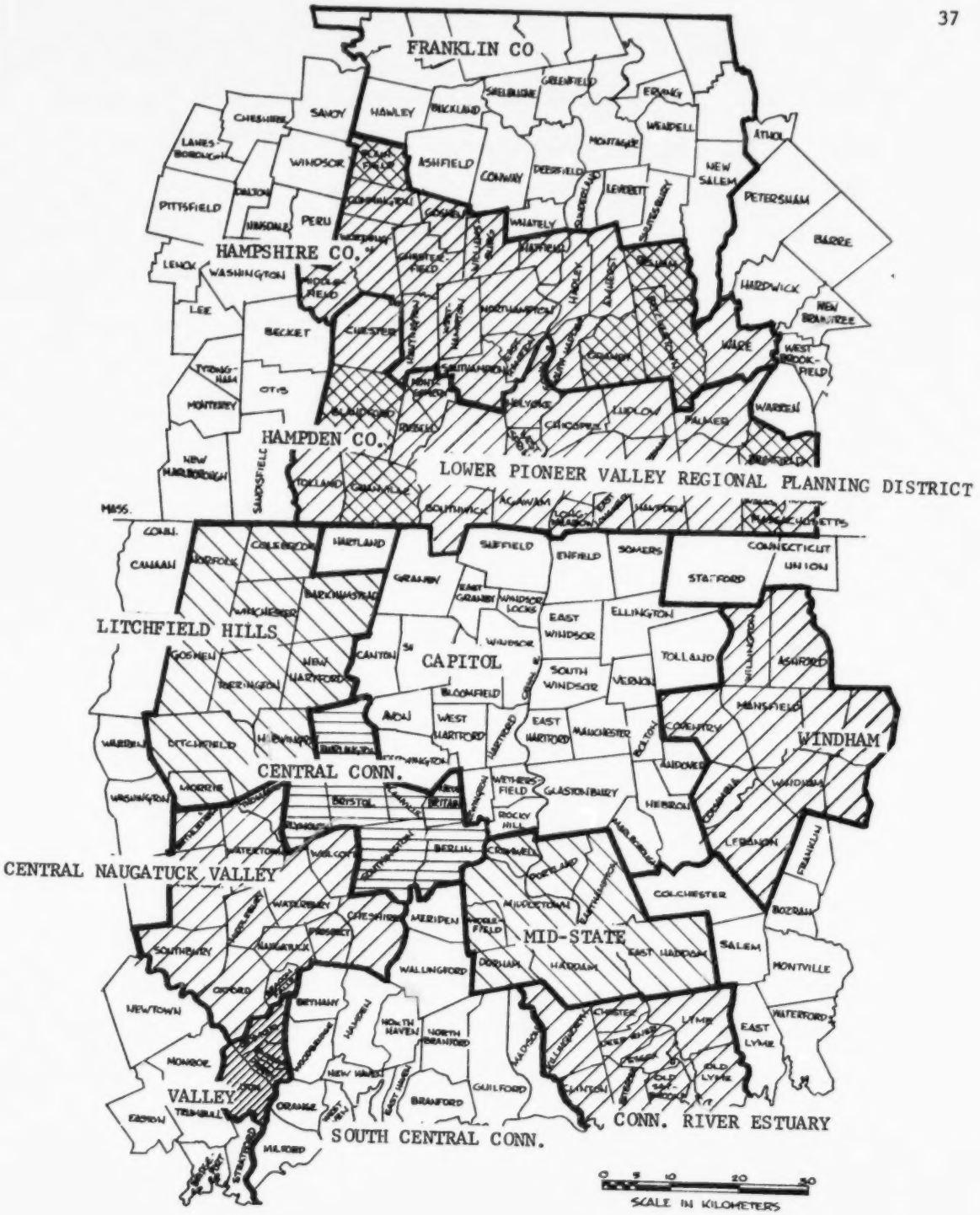


FIGURE 15. PLANNING REGIONS OF CONNECTICUT AND MASSACHUSETTS.

Planning District in Massachusetts. The District encompasses Hampden and Hampshire Counties in their entirety, with the exception of eight non-member communities. These are shown cross-hatched in Figure 15. The Planning District was established in 1962 under the State regional planning law which permits cities and towns to jointly promote the orderly development of areas within the jurisdiction of planning regions. Planning regions have been defined by the Massachusetts Department of Commerce and Development in their 1966 Interim Definition of Regions for the purpose of facilitating regional organization. One region includes all of Hampden and Hampshire Counties while another includes Franklin County.

EXISTING AIR POLLUTION CONTROL PROGRAMS AND LEGISLATION

In the process of defining the bounds of an air quality control region it becomes important to consider the role of existing State and local air pollution control programs. It is also important to review pertinent legislation which allows for the promulgation of air pollutant control regulations and which grants enforcement powers to agencies at the State and local levels. Such consideration of existing programs is mandatory since it is upon them that the ultimate responsibility for implementing region-wide air quality standards rests.

Responsibility for the control of air pollution in Massachusetts rests with the State Department of Public Health. The State Legislature has authorized the Department to adopt (minimum) State-wide air pollution regulations. The application of such regulations was intended for air pollutant emissions arising from State institutions, mobile sources, sources causing inter-municipal pollution effects, and sources which could and should be controlled by other agencies, but are not. The Department

has the authority to approve rules and regulations promulgated by local control bodies, and are further authorized to advise local control bodies in all matters of atmospheric pollution. Existing law gives local boards of health the authority to adopt and enforce air pollution rules and regulations (subject to the approval of the State Department of Public Health).

The State Department of Public Health may, upon request of the board of health of a town adversely affected by atmospheric pollution from another town, assume joint jurisdiction to regulate or control such cause of air pollution. Enabling legislation passed in 1960 authorizes the Department of Public Health, upon request of two or more contiguous municipalities within the State, to establish multi-municipal regional air pollution control districts. The Lower Pioneer Valley Air Pollution Control District was established in 1966 in accordance with this legislation. This district includes the cities of Springfield, Northampton, Chicopee, Holyoke, and Westfield and the towns of Agawam, East Longmeadow, Easthampton, South Hadley, and West Springfield. Rules and regulations to prevent and control pollution within the District have been adopted by the Department. The Department has the authority to order the cessation or abatement of any violations of these regulations, subject to penalty. The State is reimbursed by the cities and towns within the District for expenditures made for control activities within it.

In the State of Connecticut, the State Department of Health has the responsibility for the control of air pollution. Legislative authority for the control of air pollution lies in the Connecticut Air Pollution Control Law which became effective in 1967. This Law, known as Public Act

754, establishes an Air Pollution Commission which has the power to control and prohibit air pollution within the State. The Commission has the power to initiate and receive complaints and to institute legal proceedings for the enforcement of its regulations. Enforcement authority for such regulations is placed in the hands of the Commissioner of the State Department of Health.

Section 16 of the Act provides that, upon approval of the Commission, any city or town, pursuant to ordinance, may join with any other city or town or combination thereof in the formation of an air pollution control district. The Act allows for the adoption of ordinances or regulations for the control of air pollution by any city, town, borough, or district. These regulations are to be submitted to the Commission for approval.

Finally, the Act provides for the establishment of a Clean Air Task Force to formulate recommendations to the Governor and the 1969 session of the General Assembly for the development and enactment of a comprehensive, long-range air pollution control program. These recommendations as put forth, are to strengthen existing air pollution control legislation. Specifically, the Task Force has made recommendations concerning the selection of Commission members and their responsibility to determine causes and effects of air pollution. The Task Force recommendations would give greater enforcement powers to the Department of Health and would increase the severity of penalties for the violation of these regulations. Additions to the present Act would provide for an inspection system of air pollution control devices on vehicles. Also, a provision is proposed to allow for greater exchange with neighboring State air pollution control agencies if a mutual air pollution problem exists.

It is evident from the direction of legislation in Massachusetts and Connecticut that State officials recognize air pollution as a regional problem, to be approached on a regional basis. Legislation in both Massachusetts and Connecticut allows for the formation of multi-municipal districts for the control of air pollution. A 10 city and town district presently exists in Massachusetts in the Lower Pioneer Valley. Regional air pollution problem areas in Connecticut are recognized. Therefore, it appears that the idea of a regional approach to administer the air resource is shared at both the Federal and State levels.

THE PROPOSED REGION

Subject to the scheduled consultation, the Secretary, Department of Health, Education, and Welfare, proposes to designate an air quality control region for the Hartford, Connecticut, and Springfield, Massachusetts, metropolitan area. The proposed region consists of the following jurisdictions:

In the State of Connecticut:

Cities	Towns	
Bristol	Andover	Hebron
Hartford	Avon	Manchester
Middletown	Berlin	Marlborough
New Britain	Bloomfield	Middlefield
	Bolton	Newington
	Burlington	Plainville
	Canton	Plymouth
	Cromwell	Portland
	Durham	Rocky Hill
	East Granby	Simsbury
	East Haddam	Somers
	East Hampton	Southington
	East Hartford	South Windsor
	East Windsor	Suffield
	Ellington	Tolland
	Enfield	Vernon
	Farmington	West Hartford
	Glastonbury	Wethersfield
	Granby	Windsor
	Haddam	Windsor Locks

In the State of Massachusetts:

Cities	Towns	
Chicopee	Agawam	East Longmeadow
Holyoke	Amherst	Goshen
Northampton	Belchertown	Granby
Springfield	Blandford	Granville
Westfield	Brimfield	Hadley
	Chester	Hampden
	Chesterfield	Hatfield
	Cummington	Holland
	Easthampton	Huntington

Massachusetts Towns (cont.)

Longmeadow	Southwick
Ludlow	South Hadley
Middlefield	Tolland
Monson	Wales
Montgomery	Ware
Palmer	Westhampton
Pelham	West Springfield
Plainfield	Wilbraham
Russell	Williamsburg
Southampton	Worthington

As so proposed, the Region would consist of the territorial area encompassed by the outermost boundaries of the above jurisdictions and the territorial area of all municipalities located therein and as defined in Section 302(f) of the Clean Air Act, 42 U.S.C. 1857h(f). Figure 16 shows the boundaries of the proposed Region, while Figure 17 indicates the geographic relationship of the Region to surrounding areas.

DISCUSSION OF PROPOSAL

To implement a successful air resource management program, an air quality control region should be sufficiently large so as to encompass most pollution sources as well as most people and property affected by those sources. The boundaries should also encompass those locations where present and projected urbanization and industrialization will create or continue to create significant air pollution problems. Finally, the boundaries chosen should be compatible with and even foster unified and cooperative regional governmental administration of the air resource. The proposed Hartford-Springfield Interstate Air Quality Control Region was designed to satisfy, to the greatest degree possible, these requirements.

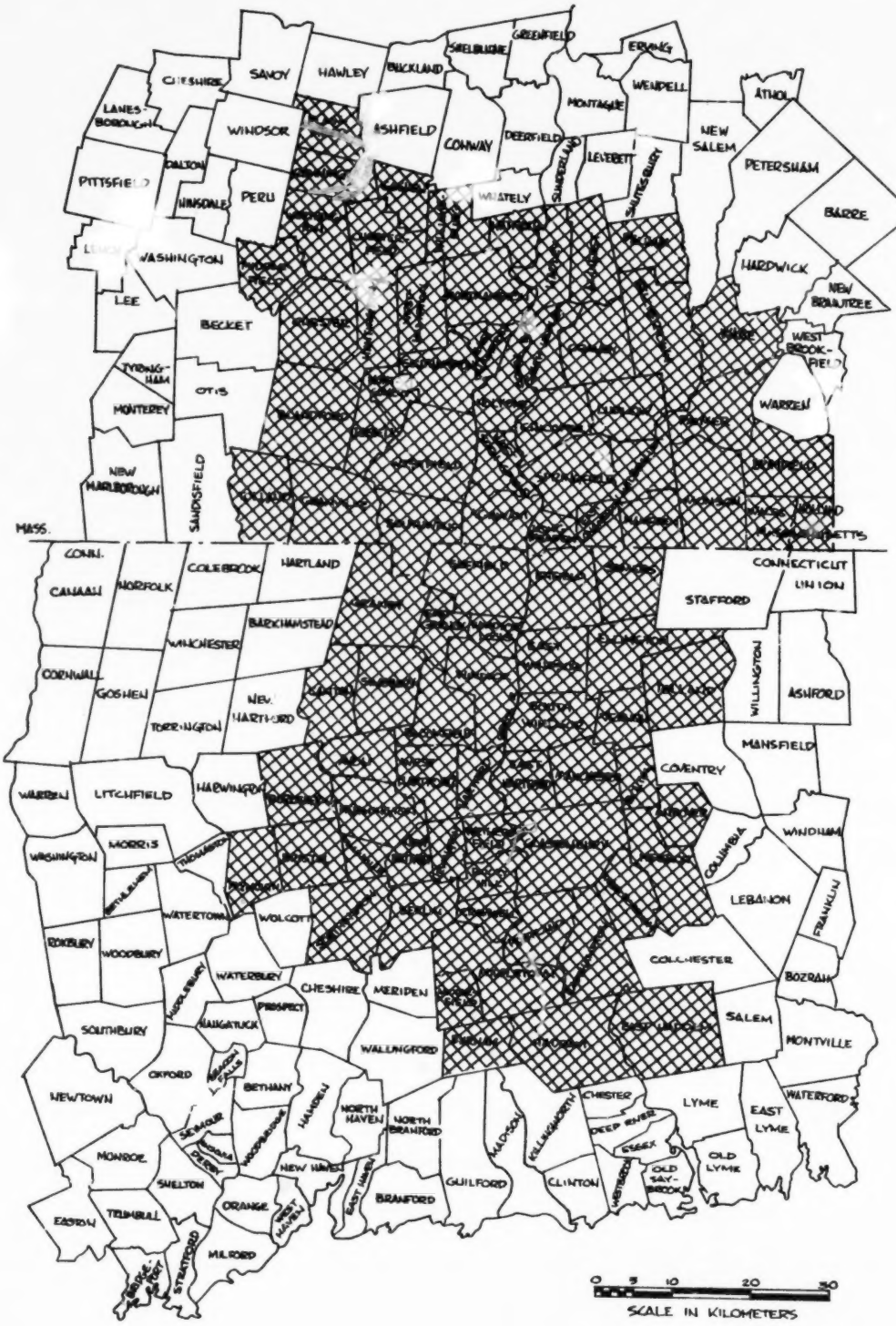
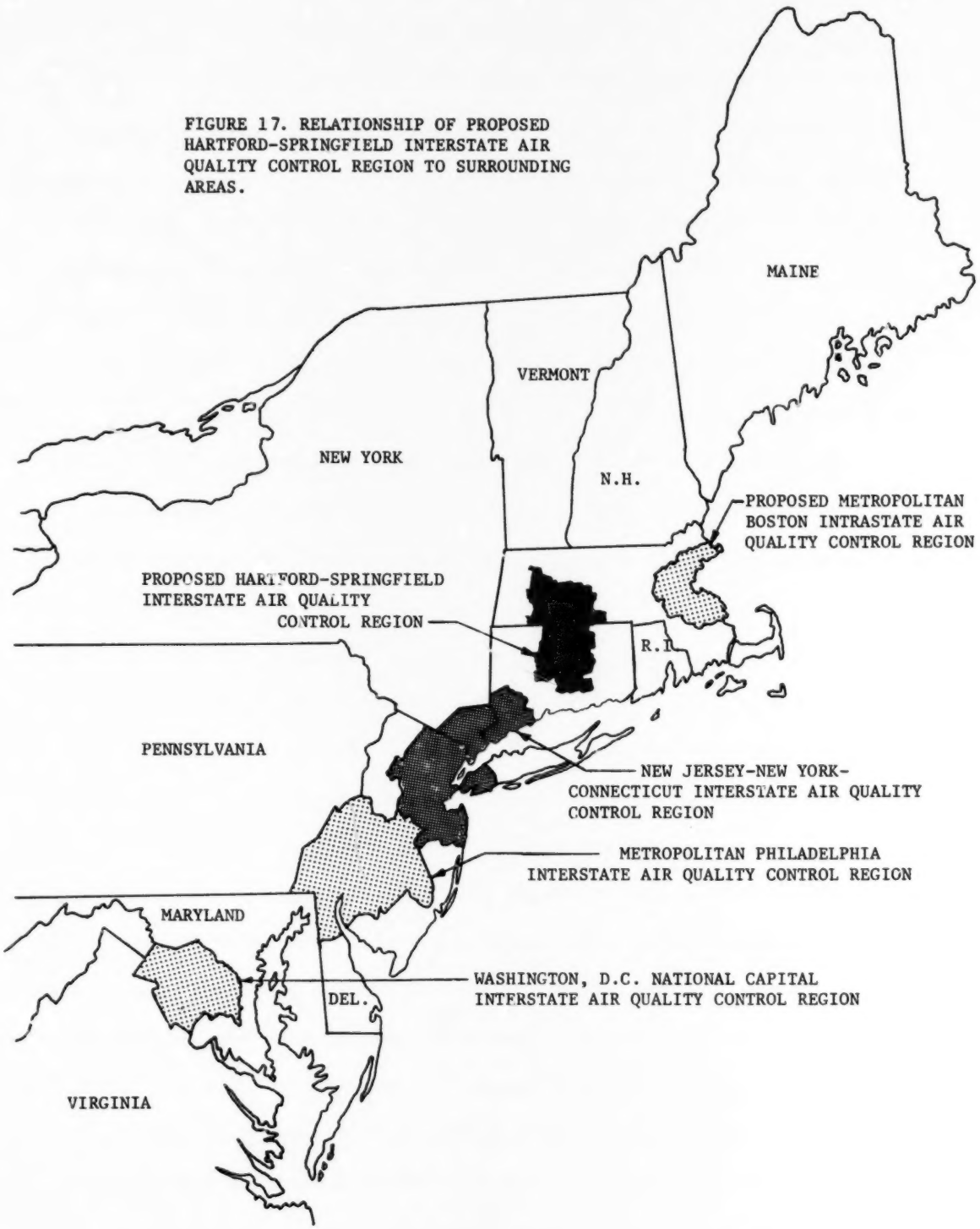


FIGURE 16. PROPOSED HARTFORD-SPRINGFIELD INTERSTATE AIR QUALITY CONTROL REGION.

FIGURE 17. RELATIONSHIP OF PROPOSED HARTFORD-SPRINGFIELD INTERSTATE AIR QUALITY CONTROL REGION TO SURROUNDING AREAS.



In most of the air quality control regions designated or proposed to date, boundaries have been determined by including or excluding counties in their entirety. This practice allows for a certain degree of latitude in evaluating, both from a technical and non-technical point of view, the geographic extent of the Region boundaries. In Massachusetts, however, counties do not exist as important decision making levels of government. Also, counties no longer function as political entities in the State of Connecticut. This necessitates the selection of Region boundaries along town lines in both States.

In Connecticut, Planning Regions have been defined according to State law. Regional Planning Agencies in each of these Planning Regions have been directed by statute to prepare and adopt regional development plans to provide a framework for local planning, and to act as a foundation for a continuing regional planning process. These Planning Regions have been defined to include a group of cities and towns that are socially, economically and culturally integrated. For this reason, the boundaries of the Connecticut portion of the Air Quality Control Region will be drawn along Planning Region boundaries in order that the subsequent administration of the air resource on a regional basis will be facilitated.

In Massachusetts, regional planning districts have been defined by the State Department of Commerce and Development for the purpose of facilitating regional organization. One such region encompasses both Hampden and Hampshire Counties while another includes Franklin County in its entirety. Also, the Lower Pioneer Valley Regional Planning District presently encompasses both Hampden and Hampshire Counties, with the exception of 8 non-member communities. Since county boundaries still function for statistical data gathering and for planning region jurisdictions, it would be advisable to follow

Massachusetts county boundaries when delineating the Region.

The results of the air pollutant emission inventory reveal that areas of major pollutant emissions coincide with the areas of most dense urbanization and industrialization in Central Connecticut and the Lower Pioneer Valley. The pattern of air pollutant emissions extends on a north-south axis from Northampton in Massachusetts southward along the Connecticut River to Middleton and then southwest to Waterbury and New Haven. In general, the most dense pollutant emissions occur in the Springfield, Hartford, New Britain, Waterbury and New Haven core areas. Sulfur dioxide emissions primarily reflect the pattern of power plant and industrial point source locations. Total particulate emissions reflect the geographical concentrations and distribution of the pollutant source-complex since most source types contribute significantly to the total amount of particulate matter emitted. Carbon monoxide emissions provide a measure of the vehicular traffic density distribution over the area, since the majority of CO emissions are attributable to the automobile.

Limited air quality data in both the Lower Pioneer Valley and central Connecticut confirms the fact that air pollutant concentrations are greatest in the areas of greatest pollutant emissions. Sampling networks in the Lower Pioneer Valley and metropolitan Hartford indicate that a significant variation in air quality exists between urban and sub-urban sampling sites. Air quality is less affected toward and at the periphery of the metropolitan areas. Even at these locations however, measured suspended particulate concentrations are greater than those measured at non-urban sites in the northeast United States.

Diffusion model results for three pollutants (SO_2, CO and suspended particulates) predict a substantial variation in air quality between the industrialized, heavily populated core-cities (Springfield, Hartford, Waterbury and New Haven) and outlying cities and towns. In general, the equal-concentration contours enclose a broad area stretching from Hadley and Amherst in Massachusetts, south along the Connecticut River Valley to Middletown and Haddam, and southwest to New Haven. Within this large area, the core-cities are recognizable since they are at or near centers of high concentrations. The air quality over less densely populated and industrialized cities and towns appears to be affected to a significant extent by pollutant emissions emanating primarily from neighboring highly-urbanized cities and towns.

Although no absolute engineering criteria exists by which the Region may be determined, it is possible to define the Region on the basis of relative pollutant emissions and concentrations in the ambient air. On this basis, it would appear that the following areas should be considered for inclusion in the Region: Hampden and Hampshire Counties in Massachusetts, and the Capitol, Mid-State, Valley, Central Connecticut, South Central Connecticut, Central Naugatuck Valley and the Connecticut River Estuary Planning Regions in Connecticut.

A study of urban factors reveals that a corridor of dense population exists from New Haven to Springfield. This band of high-density population is nearly continuous, with the exception of a few non-urbanized discontinuities. The central cities around which the greatest urbanization has occured are Springfield, Chicopee and Holyoke in

Massachusetts and Hartford, New Britain, New Haven, Waterbury, Meriden and Middletown in Connecticut. Greatest absolute population growth in Connecticut will occur in the Hartford metropolitan area while greatest increases in additional residents per square mile between 1965 and 1980 will occur in the New Haven metropolitan area. Industrial development is intense throughout central Connecticut, and particularly so in metropolitan Hartford and New Haven. Greatest growth in the Pioneer Valley in Massachusetts is expected to occur in Hampden and Hampshire Counties.

It would appear that inclusion of both Hampden and Hampshire Counties in the Region would satisfy the condition that air quality control regions include most of the present and projected population in an urban area. These two counties are expected to contain the bulk of the population growth in the Pioneer Valley. Growth in Franklin County to the north is expected to remain low. In addition, Hampden and Hampshire Counties form the boundaries of the Lower Pioneer Valley Regional Planning District.

Most of the urbanization in central Connecticut is located in the Capitol, Central Connecticut, Mid-State, Valley, Central Naugatuck Valley and South Central Connecticut Planning Regions. The inclusion of these Planning Regions in the Air Quality Control Region would result too, in the inclusion of most of central Connecticuts' population in the Region. However, an important condition which an air quality control region must meet is that it be compatible with and foster cooperative governmental administration of the air resource. Consideration given to this condition calls for the separation of the

two major metropolitan areas in central Connecticut --- Hartford and New Haven --- for the purposes of establishing an air quality control region. Thus, only the Capitol, Central Connecticut and Mid-State Planning Regions have been proposed for inclusion in the Region. The Central Connecticut and Mid-State Planning Regions appear to be more closely linked to the Hartford metropolitan area, on the basis of technical and non-technical considerations, than they are to metropolitan New Haven.

The exclusion of the Planning Regions in central Connecticut which encompass the Waterbury, Meriden, and New Haven metropolitan areas, will not prevent them from being included in a regional air pollution control effort at a later date. The National Air Pollution Control Administration (NAPCA) has recently named additional areas of concern across the Nation, to be designated as air quality control regions. Along with this list of additional metropolitan areas, to be designated, NAPCA has announced an expanded policy regarding the designation of regions in metropolitan areas not specifically named. This policy expresses NAPCA's confidence that, upon experiencing the benefits of implementing air pollution control on a regional basis, the States will, by their own initiative, adopt the regional approach to air pollution control. NAPCA encourages the States to initiate proposed boundaries in the additional metropolitan areas. Pursuant to this expanded policy, the New Haven area may be proposed by appropriate authorities of the State of Connecticut as an air quality control region. Similar proposals may be initiated by the States of Connecticut and Massachusetts for areas which they feel will benefit from the regional approach to conserving our air resource.

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6. TRC Service Corporation. An Air Pollution Study of Middletown, Connecticut. Hartford, Connecticut, September 1966.

APPENDIX A. DESCRIPTION OF DIFFUSION MODEL

The diffusion model is based on the Gaussian diffusion equation, described by Pasquill [1,2] and modified for long-term averages[3,4] for application to the multiple-source situation typical of an urban complex. The basic equation assumed that the concentration of a pollutant within a plume has a Gaussian distribution about the plume centerline in the vertical and horizontal directions. The dispersion of the plume is a function of the emission rate, effective source and receptor heights, atmospheric stability and the distance from the source. The plume is assumed to move downwind according to the mean wind.

The model was used to predict concentrations of SO_2, and CO, and total suspended particulates. The averaging times were the summer and winter seasons and the year. In order that the theoretical pollutant levels could be determined, it was necessary to evaluate certain meteorological input parameters. These parameters are wind direction and frequency of occurrence in each direction, effective wind speeds for each direction, and mixing depths for various averaging times.

Figure I-A shows the wind roses for the summer, winter, and year for the Hartford-Springfield area*. They represent graphically the frequency of occurrence of the wind from the various compass directions. This data, along with effective wind speeds for the respective compass directions was used as input data to the computerized model. The characteristic prevailing wind directions for each of the averaging times as

*U.S. Weather Bureau Data for Bradley International Airport, 1951 through 1960.

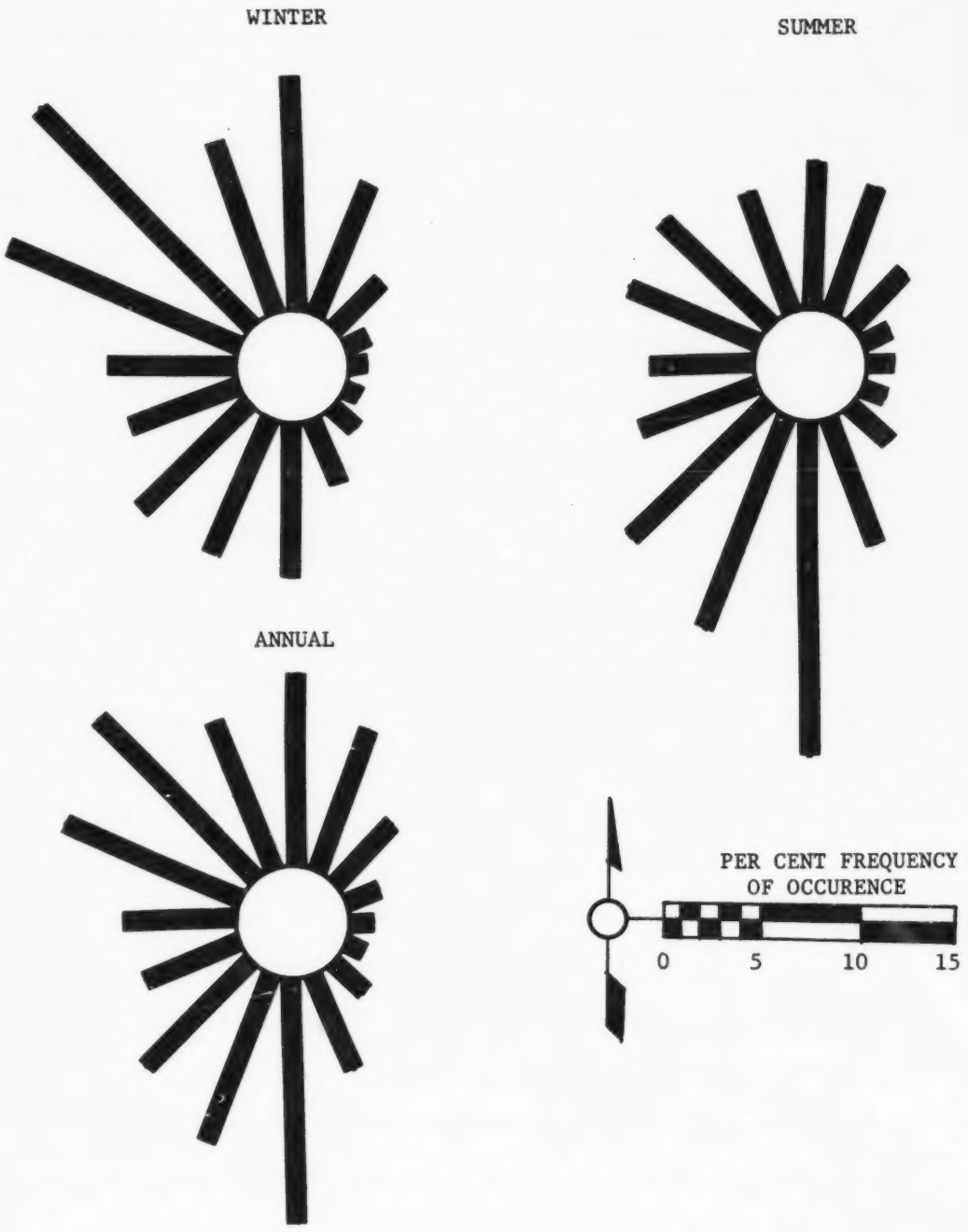

FIGURE 1-A. WIND DIRECTION PER CENT FREQUENCY OF OCCURENCE FOR VARIOUS AVERAGING TIMES.

depicted by the length of the wind rose radials, produce a direct influence over the dispersion of pollutants.

Table I-A shows average mixing depths for the winter, summer, and annual averaging periods*. A significant diurnal variation in the mixing depth is indicated. These mixing depths define the volume of air above the surface through which pollutants are allowed to mix, and are assumed to have no spatial variation (i.e., mixing depth is constant) over the receptor grid system.

Table I-A

Average Mixing Depths for Hartford
by Season and Time of Day (meters)

Season	Morning Average	Afternoon Average	Average, Morning and Afternoon
Winter	705	900	803
Summer	535	1500	1018
Annual (four seasons)	625	1176	901

The diffusion model was used to compute the ground level concentrations of pollutants at 225 receptor points. Their locations were defined by an orthogonal grid system with mest points 15 kilometers apart. This grid, 210 km. on a side, was centered in the City of Hartford. An effective source height of 75 meters was assumed for all pollutant point sources, while topographical features were neglected for area-source emissions and for the 225 receptor points.

*Computed mixing depths documented by Holzworth[5,6] and by recent tabulations furnished to the Meteorological Program, NAPCA, by the National Weather Record Center, ESSA.

APPENDIX B. REFERENCES

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